Chapter 3 Addressing Economic and Social Challenges

In order to achieve the goals set in the 5th Basic plan: Sustainable Growth and Self-sustaining Regional Development, Ensure Safety and Security for Our Nation and its Citizens and a High-Quality, Prosperous Way of Life and Addressing Global Challenges and Contributing to Global Development we will work to solve challenges strategically by exploiting all scientific and technological innovations.

Considering the reconstruction status from the Great East Japan Earthquake and other disasters, the national and local governments will work together on S&T innovations that will contribute to development of new technologies and new industries in the disaster-stricken areas.

Section 1 Sustainable Growth and Self-sustaining Regional Development

For the continued growth of Japan, it is necessary to ensure appropriate response to the increase of social costs confronting the country now and in the future. To this end, the government is advancing efforts on S&T innovations toward securing of resources, realization of sustainable society addressing super aging, etc., securing of safety and security and high-quality living.

1 Ensuring stable energy, resources, and food

(1) Ensuring stable energy and improving energy efficiency

A. Stabilizing and lowering the cost of clean energy supply

(A) Generation technologies pertaining to solar power generation system

The Ministry of Economy, Trade and Industry (METI) is conducting R&D on component technologies, toward the commercial application of innovative technologies such as Perovskite solar cells[1], the development of advanced peripherals and the maintenance technology toward improving the efficiency of the solar power generation system and developing low-cost recycling technology.

The Japan Science and Technology Agency (JST) has selected technological fields, such as solar cell and solar energy systems, in which to promote R&D on innovative technologies within a competitive environment. The targeted technologies are aimed at developments that have a high potential for greenhouse gas reduction and that are not merely extensions of conventional technologies. In FY 2017 JST started a technological development of silicon solar cells with conversion efficiency at 35% or higher.

(B) Generation technologies pertaining to floating offshore wind power plant

With an eye toward commercialization of floating offshore wind power generation systems, METI is conducting a first in the world full-scale demonstration with multiple turbines off Fukushima.

The Ministry of the Environment (MOE) conducted a demonstration project to install and operate

1 Solar cell created in Japan using materials with a crystal structure called Perovskite. Because it can be used in simple processes including application and printing, significant reduction in production costs is expected.

Japan's first 2MW floating offshore wind power plant. In order to promote floating offshore wind power generation by the private sector, the ministry has been developing and demonstrating methods for accurate and efficient survey/grasp of animals in the sea area, submarine geology, etc.; methods to reduce costs and CO_2 emissions arising from construction of floating offshore wind power plants.

(C) Generation technology pertaining to geothermal, wave power, ocean thermal energy conversion and other renewable energy systems

In order to solve challenges of geothermal power generation such as high development costs and risks, METI has been developing technology that enables gathering of more accurate data on underground thermal resources and technology to drill wells for use of geothermal resources in a short period of time and at low cost. Also under development are technologies to manage and evaluate geothermal resources necessary for stable power supply, and prevention of silica scale deposit in reducing well piping, for example.

Regarding geothermal power generation, MOE was engaged in developing and verifying a power generation system for high hot spring heat utilization and safety using a non-chlorofluocarbon agent (ammonia) with low environment load.

In order to encourage utilization of ocean energy including wave force and tidal currents, MLIT formulated safety guidelines for floating power facilities by FY2016. Nippon Kaiji Kyokai used the guidelines for certification of safety and environmental performance of the floating tidal current power facilities where the world's first demonstration was carried out in August 2017.

(D) Development of high efficiency thermal power generation systems and coal utilization technologies

METI has been implementing demonstration projects of the Integrated Coal Gasification Fuel-Cell Combined Cycle (IGFC) and development of its element technologies (including large-capacity fuel cells), development and demonstration of high efficiency gas turbine technologies and new high–efficiency power generation using coal/LNG. The ministry is also developing technologies for efficient capture and utilization of carbon dioxide (CCU) emitted from thermal power generation.

(E) Other technology development

In order to ensure production of high value added products using low cost crude oil, etc.(noble use of oil) and stable operation of refinery facilities (improvement of operation reliability) toward strengthening of international competitiveness of refineries in Japan, METI has been developing innovative oil refining technologies to extract all possible petroleum products and petrochemical raw materials from unconventional crude oil and residual oil generated in the course of refining using petroleomics technology for molecular-level structural analysis and reaction modeling.

(F) R&D related to nuclear power

i) Technologies to improve safety and nuclear security pertaining to nuclear power use

METI has been developing technologies and infrastructure under the Technological Development Program Contributing to Improvement of Nuclear Safety to enhance safety measures including

sophistication of comprehensive risk assessment of nuclear power plants. This is based on what has been learned since the accident at the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company, Inc. (TEPCO).

Japan has been working with the International Atomic Energy Agency (IAEA) and the U.S.A. in a leadership role towards advancing international cooperation related to R&D on technologies for nuclear nonproliferation and nuclear security, as well as on those related to human resources development, Japan Atomic Energy Agency (JAEA) established the Integrated Support Center for Nuclear Nonproliferation and Nuclear Security (ISCN). This center has provided training courses in nuclear nonproliferation and nuclear security. The ISCN and the IAEA have been jointly developing training programs and exchanging lecturers and information regarding human resources development based on the arrangement they made regarding the development of human resources for nuclear security. Japan-U.S.A. joint efforts have also been made in developing technology for the following: 1) the continuous monitoring of the quantity of plutonium in high-level radioactive solutions, 2) the non-destructive detection of nuclear fuel material by means of nuclear resonance fluorescence, and 3) nuclear forensics that identify the origin of illegal nuclear material.

ii) Nuclear fuel cycle technology

The Strategic Energy Plan (Cabinet Decision on April 2014) states "In order to solve problems related to disposal of spent fuels and mitigate the risks for and the burden on future generations, GOJ will make efforts to reduce the volume and harmfulness of radioactive waste and create a nuclear fuel cycle that contributes to effective utilization of resources while adequately taking the past history into consideration and continuing to seek the understanding of relevant municipalities and the international community, and will promote reprocessing and plutonium use in LWRs." Also "GOJ will promote R&D of fast reactors, etc. through international cooperation with the U.S. and France etc."

Regarding the prototype fast-breeder reactor "MONJU" the Nuclear Regulation Authority issued a recommendation to the Minister of Education, Culture, Sports, Science and Technology in November 2015 to identify the entity capable of safe output operation that would replace JAEA. In response to the recommendation, the Ministry of Education, Culture, Sports, Science and Technology (MEXT) held the Special Committee on the Management of Monju in December 2015. The committee, after examining and summarizing problems pertaining to Monju, was engaged in studies and discussions to identify requirements for the entity that will operate Monju, and compiled the results in a report in May 2016.

Considering a big change in the environment surrounding the fast reactor development in Japan in recent years, the 5th meeting of the relevant cabinet ministers on nuclear power held in September 2016 decided the "Future Plan for fast reactor development." Concerning Monju the plan calls for "implementing radical revision including decommissioning and deciding a government policy on its handling together with the policy on the fast reactor development at the meeting of relevant cabinet ministers on nuclear power within this year."

Based on the revision, the meeting of relevant cabinet ministers on nuclear power held in December 2016 decided the "policy on fast reactor development" to promote strategy development, improvement of systems, etc. in an integrated manner toward realization of a fast reactor in the future. Regarding Monju, increases in time and economic cost accompanying the new regulatory standard and uncertainty in identification of

the new operating body have been revealed, and the "policy on fast reactor development" presented a policy to work to obtain the knowledge that is expected to be obtained from resumption of operation of Monju through new measures. Based on the above, the government decided the "national policy on handling Monju" or not resuming operation of the reactors but rather to move to decommissioning while positioning the facilities for new roles in future fast reactor development. According to the policy, Monju had various problems in "management" including its maintenance system, human resource development and responsibilities of people involved, but contributed to the development of future demonstration reactors by producing various technological results concerning fast reactors through its design, construction and operation up to 40% output and by contributing to development of researchers. The policy states that "in order to decommission Monju safely and steadily, a new system for Monju decommissioning will be established as follows: (1) With guidance and supervision of the entire government, (2) undergoing technical evaluations by third parties, and (3) after establishing a system consolidating knowledge in Japan and overseas. JAEA shall implement decommissioning safely and steadily under the new system." Since deciding the policy the government has provided explanations to the local governments at various levels and gained their understanding of the decommission system of Monju. In May 2017 the government set up the Monju Decommission Promotion Team headed by Deputy Chief Cabinet Secretary assisted by Senior Vice Ministers of MEXT and METI who work as deputy heads. In June of the same year, the Conference on Monju was held to provide local governments with explanations on the basic policy of the government on Monju decommission, the basic plan (draft) of JAEA, and other matters. After the explanations, the government held a meeting of the Monju Decommission Promotion Team, decided the Basic Policy on Monju Decommission and approved the Basic Plan on Decommission of Monju. In November of the same year the Conference on Monju was held, where the process and implementation system of Monju decommission were explained, regional development measures were discussed and understanding of local people about Monju decommission was obtained. Based on the above, JAEA submitted an application for approval of decommission of the nuclear facilities of fast breeder reactor Monju to the Nuclear Regulation Authority in December of the same year. The application was approved in March 2018. MEXT and JAEA have held opinion exchange and briefing sessions with local residents toward decommission and will continue to advance decommission of Monju safely, steadily and systematically while sincerely listening to the voice of the local communities.

iii) Technologies for treatment and disposal of radioactive wastes associated with decommissioning, etc.

JAEA is making efforts to facilitate the disposal of waste from research facilities in accordance with the Basic Policy Concerning the Implementation of Land Disposal (decided in December 2008 by ministers of MEXT and METI) and the General Plan for Implementation of Land Disposal (approved in November 2009; revision approved in March 2018).

Image of a disposal facility
Source: JAEA

R&D that addresses the need to reduce the volume and hazard potential of high-level radioactive waste is a

critical national policy issue. Using an accelerator, basic study has been made on nuclear transmutation and group separation technologies.

iv) Development of technologies, etc. for decommissioning of the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company, Inc.

Toward the decommissioning of the Fukushima Daiichi Nuclear Power Station, MITI, MEXT and other relevant ministries and agencies have been taking measures in coordination and cooperation based on the Medium-to-Long-Term Roadmap towards abolition of Units 1-4 of the TEPCO's Fukushima Daiichi Nuclear Power Plant (revised on September 26, 2017). In these measures, these ministries have been supporting R&D conducted by business operators on technologies that are technically difficult and that need the government to spearhead work on them. Such R&D includes a technology for extracting fuel debris and a technology for examining the inside of reactor containment vessels.

Development of facilities to establish the technical basis for decommission is also advancing. The Naraha Remote Technology Development Center (Naraha town, Futaba-gun, Fukushima), a facility for development and demonstration of remote operation equipment/devices (mock-up facility), started full-scale operation in April 2016. In addition, for development of analysis methods, proper understanding and treatment/disposal of fuel debris and radioactive wastes, Okuma Analysis and Research Center (Okuma town, Futaba gun, Fukushima) started operation in March 2018.

International Collaborative Research Building
Collaborative Laboratories for Advanced Decommissioning Science

Based on the Acceleration Plan of Reactor Decommissioning R&D for the TEPCO Fukushima Daiichi NPS (Nuclear Power Station) (hereinafter the acceleration plan), MEXT set up the Collaborative Laboratories for Advanced Decommissioning Science under the JAEA in April 2015 to consolidate knowledge in Japan and overseas for safe, steady decommissioning. As a place for gathering knowledge within and beyond the country, the International Collaborative Research Building was opened for that center in Tomiokamachi, Fukushima Prefecture, in April 2017.

Furthermore, based on the Acceleration Plan, the operational status of the Center of World Intelligence Project for Nuclear S&T and Human Resource Development opened in FY2015 was changed from commissioned project of MEXT to a subsidy project conducted by the agency in FY2018. A system that enhanced collaboration with universities, etc. has been built around the center to promote R&D and human resource development with increased focus on the needs in actual decommission.

v) Securing and developing human resources in the nuclear field

There is the need to foster and secure a wide range of skilled human resources, in order to support the nuclear technology, ensure greater safety, and secure the safety of nuclear facilities and the smooth decommissioning of reactors in older nuclear power plants.

In the Human Resource Development and Research Program for Decommissioning of Fukushima Daiichi NPS (Nuclear Power Station) under the Center of World Intelligence Project for Nuclear S&T and Human Resource Development, MEXT in cooperation with the Collaborative Laboratories for Advanced

Decommissioning Science and others has been promoting more effective basic/fundamental research and human resource development based on the needs in the field of the decommissioning. MEXT is supporting development of human resources in an effective, efficient and strategic manner, in collaboration with the relevant sectors of industry, academia and government, and based on the Global Nuclear-HRD Initiative (GN-HRD). For the study and examination of policies for human resource development in nuclear technological fields in view of the current situation and issues, the Nuclear Human Resource Development Working Group was organized under the Nuclear Science and Technology Committee, the Subdivision on Research Planning and Evaluation, the Council for Science and Technology (CST). At the Working Group, experts from universities, research institutes and other organizations in cooperation with METI have been discussing development of professionals in universities and research facilities necessary for human resource development in the nuclear field.

METI also has been supporting human resource development using funds provided by the Expenses for Commissioning Human Resource Development toward Improving Nuclear Safety, in order to educate field engineers involved in nuclear facility maintenance and in the nuclear safety industry. This undertaking is expected to contribute to the decommissioning of the TEPCO Fukushima Daiichi Nuclear Power Station and to the safety control of other existing nuclear power stations.

vi) Basic and fundamental R&D for nuclear science

MEXT has launched strategic programs that address political requirements for the Center of World Intelligence Project for Nuclear S&T and Human Resource Development to reinforce basic and generic research. MEXT has been establishing strategic programs that address policy needs clearly and has been promoting research at universities and other research institutions under competitive research environments. In response to the new regulation standard for nuclear facilities and changes in the situation including aging of facilities, the Nuclear R&D Infrastructure Working Group that was set up under the Nuclear Science and Technology Committee, the Subdivision on Research Planning and Evaluation, and the Council for Science and Technology compiled an interim report of its discussion on the nuclear R&D functions that the state should possess, facilities necessary for maintaining them and their appropriate operation in March 2018.

JAEA is conducting basic and fundamental research on nuclear engineering, reactor engineering, irradiation materials science, partitioning and transmutation technology, radiochemistry, computational science, advanced nuclear science and related areas. R&D has been promoted for improved safety and the diversified application of high-temperature gas-cooled reactors, with high potential for widespread industrial use in power generation and hydrogen production in addition to the inherent safety.

vii) Efforts for understanding and co-existence with the public

MEXT has been supporting projects to deepen the understanding of the facilities among people nationwide and in regions where those facilities are located, towards the sustainable development of the region and education on nuclear power and other energy sources.

viii) International nuclear energy cooperation

For R&D on highly sustainable nuclear energy systems, Japan is collaborating in various fields with the United States, France and other countries that are advanced in the use of atomic energy. This collaboration

falls under frameworks such as the Generation IV International Forum (GIF).

The Ministry of Foreign Affairs has been supporting the promotion of the peaceful use of nuclear science and technologies by IAEA and member countries' efforts to achieve Sustainable Development Goals (SDGs). Through financial support to IAEA with contribution to Peaceful Use Initiative (PUI) and strengthening of collaboration between IAEA and Japanese universities, research institutions and companies with expert knowledge and technologies, the ministry has been promoting capacity building of developing countries and supporting international deployment of excellent human resources and technologies of Japan.

MEXT has been leading the way in the peaceful use of nuclear energy and in nuclear non-proliferation by contributing to projects implemented by the IAEA and the Nuclear Energy Agency under the Organization for Economic Co-operation and Development (OECD/NEA). Also, as part of MEXT's contributions to the Forum for Nuclear Cooperation in Asia (FNCA), most of whose members are Asian countries, MEXT has been supporting FNCA member countries in their R&D and infrastructure development for the use of radiation and nuclear research reactors, for example.

METI also has advanced R&D for the establishment of verification technology for fast reactors by means of Japan-French cooperation and other international cooperation frameworks. Fast reactors are expected to contribute to reductions in toxicity and in the volume of radioactive waste.

ix) Efforts pertaining to the peaceful use of nuclear energy

Japan concluded IAEA in 1977 and signed the Additional Protocol in 1999. Pursuant to the agreement and the protocol, Japan has been complying with IAEA safeguards whereby IAEA verifies that nuclear materials are used only for peaceful purposes and are not diverted or misused for nuclear weapons assembly. Thus, pursuant to the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (Law No. 166 of 1957) (Nuclear Reactor Regulation Law), Japan has been implementing a system of accounting for and controlling nuclear material, providing reports to IAEA, and accepting IAEA inspections.

IAEA: in its safeguards implementation report, concluded that all the nuclear materials in Japan are used solely for peaceful purposes in 2016 as well. Broader Conclusion has been reached since the implementation result in 2003.

x) R&D of super-long-term energy technologies

Fusion energy is expected to be the prime energy source in the future, because fuel resources abound, no greenhouse gases are emitted during power generation and small amounts of fuel can generation power on a large scale. It could completely solve energy and global environmental problems. With regard to the application of fusion energy, three types of reactor have been the subject of advanced R&D and have produced world-class results in fusion: 1) the Tokamak reactor (The National Institutes for Quantum and Radiological Science and Technology, High-Performance Fusion Experiment System: JT-60SA[1]), 2) a helical reactor (National Institute for Fusion Science (NIFS) and the Large Helical Device (LHD)) and 3) a laser fusion reactor (Institute of Laser Engineering, Osaka University, GEKKO-XII Laser).

---

1 In August 2008, operation of the JT-60 break-even test facility was suspended. The facility was subsequently dismantled for repair and is now being reassembled as the JT-60SA.

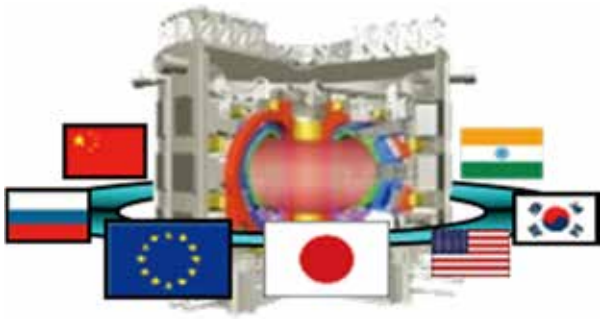
Based on international agreements, Japan has also been taking part in the International Thermonuclear Experimental Reactor (ITER) Project[1], which demonstrates the scientific and technological feasibility of fusion energy through the construction and operation of an experimental reactor. Japan, in partnership with Europe, is also advancing fusion R&D in Rokkasho Village (Aomori Prefecture) and Naka City (Ibaraki Prefecture) under Broader Approach (BA) activities that complement and support the ITER Project.

Space-based solar power that can stably supply clean energy free of natural conditions such as it being daytime or nighttime and the weather is expected to become an innovative energy technology in the future.

Toward realization of space-based solar power, METI has been conducting R&D on its core technology, wireless power transmission and reception using micro waves. The focus of the R&D is on enhancement of the efficiency of the power transmission and reception part and making it thinner and lighter.

Japan Aerospace Exploration Agency (JAXA) has been conducting R&D of elemental technologies toward practical use of space-based solar power.

International Fusion Energy Research Center (Rokkasho Village, Aomori Prefecture)
Source: QST



ITER (International Thermonuclear Experimental Reactor)
©ITER Organization

B. Stable energy use using energy storage technologies including hydrogen/storage batteries

The Cabinet Office has been working on the SIP "Energy Carrier" since fiscal 2014. With the aim of building a CO2-free value chain using hydrogen derived from renewable energy, etc. the project has been developing technologies for efficient production, transportation, storage and use of hydrogen.

METI is conducting the technological development and demonstration of batteries and fuel cells. Specifically, the ministry conducted technological development of optimal control and management methods when introducing large batteries for power systems that will become necessary with the expansion of renewable energy introduction. Technological development was conducted also for the performance enhancement and cost reduction of lithium-ion and post lithium-ion batteries for next-generation vehicles, such as plug-in hybrids or fully electric cars. R&D on fuel cells for domestic use and other fixed uses, and on vehicle fuel cells, has focused on lowering costs while increasing durability and efficiency. Toward further spread of fuel-cell vehicles, the ministry had installed about 100 hydrogen stations, mainly in four major cities, as of FY 2017.

METI also has launched the R&D of Innovative Utilization Technology of Wasted Heat Energy project,

1 This project is for demonstrating the scientific and technological feasibility of fusion energy through the construction and operation of an experimental fusion reactor based on a seven-party international agreement (Japan, EURATOM, the U.S.A., Russia, China, South Korea and India) on the application of fusion energy, which is expected to completely solve energy and environmental problems.

towards reducing and utilizing waste heat energy that has been emitted to the environment through inefficiency usage. Through the advancement and practical application of fundamental technologies, including those for heat insulation and for the storage and transformation of heat energy, the use of heat pumps and the development of thermal management technologies that combine the aforementioned technologies, the ministry has been working to save energy and to reduce carbon dioxide emissions.

The JST has been promoting competitive R&D of innovative technologies that have a big potential for greenhouse gas reduction and that are not an extension of an existing technology, which include next-generation storage batteries with vastly higher performance than current batteries.

C. Improvement of energy utilization efficiency and consumption reduction using new technologies

METI has been conducting a demonstration of a virtual power plant that remotely integrates and controls consumer-side energy resources spread across the power grid including energy facilities such as renewable energy power facilities and storage batteries, and demand response, to make them function as one power plant and use them for adjustment of supply and demand. METI has been supporting construction of an energy system based on local production and local consumption for coordinated utilization of local energy in a defined area, which includes renewable energy heat such as waste heat energy emitted to the environment through inefficient usage and sewage heat, and renewable power such as solar power by using an energy management system. The support covers the commercialization feasibility study, development of the master plan and system construction, in order to promote the further spread of renewable energy and efficient use of energy.

The Ministry of Environment has been implementing projects to establish an advanced model for implementation of CO_2 emissions reduction measures with high cost performance across regions by introducing independent/distributed energy systems that will use renewable energy, independent cables, etc. in public and other facilities together with energy-saving renovation, which will be followed by optimization of energy supply and demand beyond individual districts.

RIKEN (Institute of Physical and Chemical Research) has been conducting R&D on technologies for devices that realize radical lower power consumption and great improvement of energy conversion efficiency, with creating new materials science that enables innovation in electricity consumption under completely novel concepts.

JAXA has been conducting R&D on lowering the fuel consumption and environmental load of airplanes. JAXA intends to accelerate R&D in this area because it is directly related to international competitiveness. JAXA intends to make the aeronautics industry a super-growth industry that rates on par with the automobile industry. For instance, R&D will address technologies for making engines lighter and more efficient, and technologies for reducing noise from the airplane body, while taking into account the potential R&D trend for next-generation airplanes and beyond. While preparing, maintaining and improving large-scale experimental facilities (wind tunnels and Ground-Level Enclosed Jet Engine Test Facility), JAXA will transfer innovative aeronautic technologies to other industries wherever feasible.

The New Energy and Industrial Technology Development Organization (NEDO) implemented the Strategic Innovative Energy-Saving Technology Program through open public invitations for proposals. The program focuses on key technologies listed in the Strategy for Energy Efficiency Technologies 2016

(formulated in September 2016), for effective promotion of R&D and the spread of energy-saving technologies.

The Building Research Agency has been conducting R&D for environmentally-sound and efficient use of resources/ energy in housing, construction and urban planning fields.

D. Application of innovative materials, devices, etc. to a broad range of areas

Toward realization of power devices using gallium nitride (GaN), etc. which will enable significant reduction of power consumption, MEXT has been promoting R&D on the next-generation semiconductor integrally from materials processing to device and system application also using theories and simulations. In FY 2017 the Ministry started research on implementation techniques of innovative laser devices.

The JST has selected technological fields, such as ultra heat-resistant materials, high quality recyclable steel and innovative energy-saving/creating chemical processes to promote the R&D on innovative technology within a competitive environment. In FY2017 JST succeeded in developing high-speed self-healing ceramics applicable to members of aircraft engine.

The National Institute for Materials Science (NIMS) has been promoting R&D for stable energy supply and efficient energy use. The R&D includes: high-efficiency batteries or solar cells for construction of network systems that promote use of diverse energy sources; energy conversion/storage materials for effective use of energy; R&D toward the breakthrough of high-output semiconductors for energy conservation, high-luminance light materials, etc.; high-efficiency/performance transportation equipment materials and energy infrastructure materials contributing to a low environmental burden society.

METI has been developing technologies for: producing plastic materials and other major chemical products from carbon dioxide and water using solar energy (artificial photosynthesis project); highly efficient production of organosilicon materials without using metallic silicon; production of chemical products such as engineering plastic from inedible biomass and other materials; accurate and speedy evaluation of performance and characteristics of electronic device materials (lithium-ion cells and organic thin film solar cells); application of printing technology to produce electronic devices with significantly greater energy saving and efficiency at lower cost compared with conventional ones, and; integrated manufacturing process and component production of highly functional lignocellulose nanofiber.

(2) Ensuring stable resources and cyclical use

A. R&D of seabed resource exploration/production

In FY2014, the Cabinet Office started to work on a new research project of Next-Generation Technology for Ocean Resources Exploration under the cross-ministerial SIP. This project aims at establishing technologies for efficiently surveying cobalt-rich crusts and submarine hydrothermal deposits containing copper, zinc and rare metals before the rest of the world. These technologies will help create a marine resource survey industry.

MEXT has been developing advanced key technologies necessary for ocean resource exploration and is using these technologies for research and exploration. Within the framework of the program for developing technologies for promoting the use of marine resources: system development for the wide-area exploration of ocean mineral resources, which started in FY2013, MEXT aims at promoting the transfer of

technologies to private companies. For this purpose, cutting-edge sensor technologies developed by universities have been further advanced, efficient wide-area exploration systems have been developed by combining multiple sensors, and new exploitation techniques have been developed and verified for practical application.

MLIT aims at market expansion in relation to ocean development. For this purpose, the ministry has been supporting technology development for floating liquefied natural gas (FLNG) operation facilities and autonomous unmanned underwater vehicles (AUVs) for maintenance of underwater facilities, because the demand for these facilities is expected to grow.

Japan Agency for Marine-Earth Science and Technology (JAMSTEC) has been conducting R&D for clarification of the origin of seafloor resources and establishment of effective survey and environmental assessment methods using ships, probes, cutting-edge sensors and other technologies toward sustainable use of resources buried in the sea areas surrounding Japan. In FY2017 JAMSTEC discovered a thick cobalt rich crust spreading on a slope of an undersea mountain near the mainland island from 1,500 meters to 5,500 meters below the surface of the sea through efficient survey using unmanned probes.

The National Institute of Maritime, Port and Aviation Technology (MPAT) is conducting R&D pertaining to oceanographic observation, offshore exploration, submarine construction, transportation/communication between ocean base and sea floor, transportation/guiding from a base on the land to a base on the sea, etc. MPAT is also conducting research on the development and improvement of techniques for safety evaluation of offshore structures and for reducing environmental impacts. These techniques are the basis of key technologies for the exploitation of ocean resources and energy.

B. R&D on technologies for resource saving and substitute materials of rare earths and rare metals

To overcome the constraints imposed by the scarcity of certain elements, such as the rare earths and rare metals that are necessary for next-generation cars and wind power generation and also to save energy, MEXT and METI have been conducting mutual R&D on materials.

To overcome Japan's resource constraints and improve its industrial competitiveness, MEXT is promoting the Strategy for Rare Elements Project (research center development type) in order to find completely new materials that eliminate the need for scarce elements such as rare earth and rare metals by theoretically elucidating and applying the functions of elements.

METI has developed materials that are more magnetic than conventional ones and that greatly reduce use of rare metals in the Technological Development of New Structural Materials Contributing to Drastic Weight Reduction of Transportation Equipment. Furthermore, in order to promote effective use of Japan's urban mines[1] and realize stable supply of resources as well as resource and energy conservation under the R&D on Recycling Technology to Build, a Highly Efficient Resource Circulation System, the ministry developed technologies for automatic sorting of waste products and components and high-efficiency refining.

1 Useful metals in the enormous quantity of disposed home appliances are likened to a mine

C. Development and demonstration of biomass utilization technologies

For biomass energy, METI is conducting R&D to increase the efficiency of a cellulosic ethanol production process while reducing its costs, and to introduce and disseminate next-generation biofuels, such as algal biomass, that are compatible with food production.

The ministry is also promoting the development of technologies capable of producing substances that were previously difficult to synthesize, significantly improving the production efficiency of useful materials, reducing energy consumption in material production, vastly reducing environmental loads and dramatically improving the development efficiency of lightweight, high-performance materials through genetic design and recombinant technologies based on large-scale genome information.

MOE is conducting R&D and verification for technology to realize the combustion of fuels with a high-ratio of biomass, included as fuel for thermal power generation plants, with the aim of reducing carbon dioxide emissions.

The JST has been promoting R&D on innovative technologies within a competitive environment, which include a consistent process of synthesizing next-generation chemicals breaking away from fossil resources. In FY2017, JST started R&D for creation of the next generation materials such as films and porous materials through precise control of the surface of cellulose nanofiber.

RIKEN has been conducting leading studies on the cyclic use of carbon, which has been consumed in petrochemical products, through interdisciplinary studies on plant science, microorganism science and biochemical and synthetic organic chemistry. Another RIKEN endeavor is R&D on the establishment of innovative bioprocesses towards the discovery of new materials derived from biomass.

The Public Works Research Institute is conducting research on effective utilization of resource and energy with a focus on sewage facilities.

(3) Securing a stable food supply

Aiming at stable food supply, productivity improvement of agriculture and other purposes, the Ministry of Agriculture, Forestry and Fisheries (MAFF) is conducting research to develop super-high-yielding crop varieties, crops suitable for harsh environments, and breeds of cow with high lifetime productivity. To help achieve Japan's food self-sufficiency target, MAFF is also working to develop food and feed crops that have novel features in terms of quality and processability and techniques for differentiation and quality improvement of livestock products by using domestic feed.

In order to realize new agriculture (smart agriculture) that will achieve super labor saving and high quality production utilizing robotics and information communication technologies (ICT), in FY2017 MAFF constructed a system of visualization of knowhow of skilled farmers using artificial intelligence (AI), IoT, etc., and conducted research on advanced production management using ICT, an automated driving system of farm machines using satellite positioning information, and robots for levee weeding and harvesting, for example. The ministry also worked for verification of the safety and established rules for robotics that requires solution of safety issues before installation in the field and for standardization of agricultural information for utilization of ICT in agriculture in cooperation with other ministries and agencies. With cooperation of relevant ministries, private companies, universities and national research and development agencies, MAFF worked to construct the Agriculture Data Coordination Platform to create

an environment for data utilization in farming.

With the aim of sustainable harvesting of marine biological resources, MEXT has been conducting R&D to clarify the physiology of marine organisms for innovative production under "sophistication of technologies to secure living marine resources" among the programs to develop technologies that promote use of marine resources.

The Public Works Research Institute is implementing research on improvement and maintenance of agricultural production base in snowy cold regions to contribute to enhancement of the food supply, and fisheries base in cold sea to contribute to enhancement of the food supply.

Column 2-4

Developing agricultural machinery automation technologies

Labor shortage due to the decreasing number of farmers and aging has become a serious problem of agriculture in Japan. There is an urgent need to dramatically save labor and improve productivity of farm work by using robotics, etc.

To address this problem, National Agriculture and Food Research Organization (NARO) developed an automatic driving rice planting machine that can be used for unmanned operation (currently under verification test). Conventionally rice planting required one operator and one seedling feeder, but the new machine that eliminates the need for operator will enable planting by one seedling feeder. In addition, its automatic steering system enables straight driving and turning with the precision of skilled operators.

Automatic driving rice planting machine under unmanned operation
Source: NARO

Other developments include robot tractors that can travel automatically under human supervision and an automatic paddy water management system that can be remotely controlled. Their introduction in actual farming is expected in the near future. We are now close to realization of new farming where utilization of robotics and other technologies enable ultra labor-saving and high-quality production.

Table 2-3-1 Major projects for stable supply of energy, resources and food (FY2017)

Ministry	Implemented by	Project
MEXT	MEXT	Grants for area-locating electric power stations
		Grants for promoting the development of power supply regions
		Grants for nuclear fuel cycle-related promotion coordination, etc.
		Commissioning expenses for nuclear system R&D
		Center of World Intelligence Project for Nuclear S&T and Human Resource Development
		R&D on next-generation semiconductors contributing to realization of energy-saving society
		Expenses necessary for promotion of the International Thermonuclear Experimental Reactor (ITER) Plan
		Expenses necessary for promotion of Broad Approach (BA) activities
		Businesses related to nuclear non-proliferation and security

MAFF	MAFF	Next-generation greenhouse horticulture support program
		R&D for constructing value chains connected by technology
		Strategic project research promotion program
		R&D for strengthening production sites

METI	METI/ Agency for Natural Resources and Energy (ANRE)	Subsidy to support promotion of energy saving investments
		Subsidy for operating costs of energy-saving diagnosis of SMEs
		R&D on hyper spectrum sensors for remote detection of oil resources
		Program to promote development of innovative energy saving technologies
		Subsidy for development and operation costs of hydrogen stations to promote spread of fuel cell cars
		R&D of recycling technologies for construction of a highly efficient resource circulation system
		Commissioning expenses of experimental study of floating offshore wind power generation system off Fukushima
		Subsidy to support R&D on highly efficient oil refining technologies
		Subsidy for demonstration of virtual power plant construction using energy resources on demand side
		R&D of technologies to address power variation of power system
		Development of a next-generation offshore DC power transmission system
		R&D for cost reduction of offshore wind power generation, etc.
		R&D of ocean energy power generation technologies including wave force and tidal currents
		R&D to reduce costs of solar power generation
		Technology development for construction of a bio fuel production system
		Technology development to reduce the cost of using renewable heat energy such as earth thermal
		Technology development to expand introduction of geothermal power generation
		Grant for expenditures for promotion of introduction of clean energy cars
		Commissioning expenses for technology development on stratum disposal of high-level radioactive wastes, etc.
MOE	NRA	Expenses for commissioning work on improvements to nuclear fuel research safety technologies for nuclear fuel cycle facilities
		Development of Criticality Risk Evaluation Methods
		Research on safety regulation related to external events in reactor facilities
		Research on regulations for reactor design review
		Expenses necessary for radiation survey and research expenses
		Research for sophistication of examination/regulation of safety design to prevent severe accidents of power reactors
		Research on volcano hazard assessment

2 Achieving a sustainable society to handle hyper-aging, depopulation, etc.

(1) Establishment of a society in which people enjoy long and healthy lives with world-leading medical technology

In order to contribute to the realization of a society where citizens stay healthy and live longer, medical

R&D that will contribute to the provision of world-leading medical care and to the generation of industrial activities for the realization of such a society will be promoted in a planned and comprehensive manner. To this end, efforts are being made under the leadership of the Headquarters for Healthcare Policy, and, based on the Healthcare Policy (Cabinet Decision on July 22, 2014, partially changed on February 17, 2017) and the Plan for Promotion of Medical Research and Development (decided by the Headquarters for Healthcare Policy on July 22, 2014 and partially changed on February 17, 2017).

With the aim of promoting implementation of clinical trials by ensuring the confidence in them, the Clinical Trials Act (Act No. 16 of April 14, 2017) was enacted in April 2018. The act establishes procedures for the conduct of clinical trials, measures for appropriate provision of reviews and opinions by the certified review board and systems such as publication of information on provision of funds and other benefits for clinical trials.

A. Drug discovery

(A) Promotion of drug discovery research

To improve drug development and medical technology support bases that link high-quality basic research results with the commercialization of innovative drugs, through AMED, MEXT has been implementing the Platform Project for Supporting in Drug Discovery and Life Science Researches to allow industries and universities to share information by developing technological bases, for example, a world-class level radiation facility, a compound library facility and protein production and bioinformatics technology facility and genome/epigenome analysis.

RIKEN is promoting the advancement of structural prediction technology, etc. using protein production technology, structure and function analysis technology and computational science. Riken is also conducting pioneering research on state-of-the-art technology for measurement, quantification and modeling of life phenomena and for the reproduction of cell functions.

AMED under the Advanced Research & Development Programs for Medical Innovation and the JST under the Strategic Basic Research Programs (see Chapter 4 Section 2, 1 (2)) are conducting research to create fundamental technologies in this field. These programs are conducted in coordination with the programs described above.

The Ministry of Health, Labour and Welfare (MHLW) has been implementing the Project Promoting Support for Drug Discovery through AMED. The project aims at early practical application of excellent drug seeds of researchers of universities, public research institutions, etc. through technical support, support for biomarker search, non-clinical trials, intellectual property management, and through bearing of expenses of these activities. In order to help pharmaceutical approval of the results of basic research produced in Japan and create innovative medicine, the ministry has been implementing the "Project to Promote Clinical Study and Trials" to promote high-quality clinical study and trials led by doctors where science and ethics are sufficiently secured. Toward development of innovative medicines, MHLW has been implementing the "Research Project to Promote Development of Infrastructure for Drug Discovery to promote drug target/biomarker search in industry-academia-government collaboration, construction of next-generation drug seeds library and research on technology development for drug discovery.

Through AMED, METI has been conducting the Development of Technology for Measuring miRNAs

in Serum program. Under the program, METI has accumulated large amounts of clinical information and biobank specimens. Using these, METI aims to achieve the following: the early discovery of markers for 13 cancers, including breast and bowel cancer, and for dementia; the practical use of less invasive and highly sensitive diagnosis system technology.

(B) Innovations in biomedical structural and synthesis technology

Through AMED, MEXT has been conducting the Basic Science and Platform Technology Program for Innovative Biological Medicine to assist in developing innovative basic technologies in universities for producing Japanese next-generation, innovative biomedical drugs.

MAFF launched a workshop of experts to establish the world's first fundamental technologies to produce biomedicine and test drugs using silkworms and other local resources and accelerate their industrial use. The ministry has been promoting related R&D.

To develop medicines with high healing effects and minimal side effects, through AMED, METI has been establishing basic production technology for next-generation antibody drugs that meet international standards, as well as developing innovative drug discovery processes.

B. Development of medical equipment

Through AMED, MHLW is implementing the "Project to Promote Development of Medical Equipment" with the aim of providing safer treatments for patients. The project is promoting the development of diagnosis support software that supports accurate and speedy diagnosis by doctors and development of non-invasive/minimal invasive medical equipment.

Through AMED, METI has been implementing the Program to Promote Commercialization in Medical-Engineering Collaboration in order to promote development and commercialization of medical equipment that meets needs in medical practice by taking advantage of manufacturing technologies of Japan. In FY2017 the program supported 39 medical equipment development projects. Furthermore, the ministry has been implementing the "Program for R&D on Medical Equipment/Systems for Future Medical Care" with the aim of promoting development of innovative medical equipment based on the results of excellent basic research. The program has been promoting development of innovative medical equipment/systems made in Japan taking advantage of robotics, diagnosis and other technologies where Japan has strengths. In cooperation with MHLW, METI has prepared a guideline for development of medical equipment to clarify detailed evaluation criteria contributing to the technological and biological stability of medical equipment towards future practical application, in order to promote the development of medical equipment.

The Pharmaceuticals and Medical Devices Agency (PMDA) conducted the regulatory science strategy consultations and comprehensive regulatory science consultations for practical application of excellent seeds held by academic startups, etc.

C. Establishment of centers to create innovative medical technologies

MEXT, in cooperation with MHLW and through the Japan Agency for Medical Research and Development, has been promoting the Strategic Translational Research Promotion Program that aims to

strengthen ability to nurture seeds in and outside of centers, and establish permanent centers. AMED has been working on establishing a system for putting basic research outcomes to practical use in a consistent way.

In order to promote high-quality clinical studies necessary for development of innovative Japanese medical drugs and devices, since 2015 MHLW has been approving hospitals that play a central role in international-standard clinical study and doctor-centered clinical trials as clinical study core hospitals based on the Medical Care Act (Act No. 205 of 1948) and promoting the Project for Comprehensive Promotion of Practical Use of Medical Technologies through AMED.

D. Realization of regenerative medicine

Aiming at the early realization of regenerative medicine and drug development using stem cells, including iPS cells, the ministries concerned are promoting research in close cooperation with each other. They are working on establishment of a research system and securing of research funds, and the securing and management of intellectual properties, for example.

MEXT, in cooperation with MHLW and METI, is promoting the world's first implementation of regenerative medicine and innovative drug development using iPS cells and related materials. To this end, AMED at the Research Center Network for the Realization of Regenerative Medicine is constructing a nationwide framework by enhancing core center functions and improving networking. Basic research is conducted also in JST Strategic Basic Research Programs (see Chapter 4 Section 2, 1(2)) as well as at RIKEN.

MHLW continuously supports endeavors that have moved from the nonclinical phase to the clinical phase. Through AMED, MHLW is also promoting research on basic technologies that will contribute to the search and selection of candidate compounds for medicines using human iPS cells. MHLW is seeking to establish a base of technology for safe and effective regenerative medicine that uses human cells, such as iPS cells, to promote research into tumorigenicity, rejection and other areas, which are hurdles for the early clinical application of regenerative medicine.

Through AMED, METI is implementing the Project Focused on Developing Key Evaluation Technology, Aiming at Industrialization in the Field of Regenerative Medicine. The ministry clarified the safety evaluation items specific to each regenerative medicine product and developed a reasonable evaluation method. And METI is promoting the development of basic technologies for the stable mass production of high-quality stem cells, such as iPS cells, that will be needed for regenerative medicine, and the development of basic technologies for safety evaluation of medicine candidates in the application of regenerative medicine.

E. Realization of Tailor-made Genome Medical Treatment

Through AMED, MEXT is implementing the Tailor-made Medical Treatment with the Biobank Japan Program (the 3rd term) and established one of the world's largest biobanks of patient DNA, biological samples and clinical information collected from cooperating medical institutions. MEXT is also promoting the Tohoku Medical Megabank Project, which is a long-term genome cohort study on areas affected by the Great East Japan Earthquake. The project intends to promote long-term epidemiological research (genomic cohort research), to restore community medical systems in the affected regions and to attain next-generation medical care, such as personalized prevention. Furthermore, through AMED, the ministry has been

promoting the Platform Program for Promotion of Genome Medicine to restructure the existing biobanks, etc. described above into hubs for research bases/cooperation while at the same time to carry out cutting-edge R&D with defined goals in an integrated manner using the research bases.

F. Cancer research

In Japan, one in two people will develop cancer. One in three people die from the disease (about 370,000 persons/year as of FY 2016.) Cancer remains a serious problem for life and health.

Therefore, aiming at joint efforts by patients and society, the government has promoted studies on cancer with a permanent cure and prevention in mind and on living with cancer. These efforts are based on the Comprehensive 10-Year Strategy for Cancer Control (decided by the Ministers of MEXT, MHLW and METI on March 31, 2014) that establishes the future direction of cancer research to be advanced by the whole country, specific research items and other matters. Based on the Cancer Control Act (Act No.98 of 2006), the 3rd Basic Plan to Promote Cancer Control Programs (Cabinet decision on March 9, 2018) was formulated with the overall objective: "the public including cancer patients know cancer and aim to overcome cancer." The plan incorporates focused promotion of genomic medicine and immune therapy which promise development of new treatments. In keeping with the goals set in the plan: (1) enhancement of cancer prevention and screening based on scientific evidence; (2) realization of patient-centered cancer treatment, and;(3) creation of a society where people can live with dignity and in safety, we will further promote research in accordance with the progress of science and technologies and clinical needs.

MEXT, through AMED and in cooperation with MHLW, METI and others, has been implementing the Project for *Cancer* Research and Therapeutic Evolution. In order to create next-generation cancer therapies, this research program promotes research aimed at elucidating the biological properties of cancer, research based on patients' clinical data including cancer genome information, and research combining both aspects.

Through AMED, MHLW is implementing the Practical Research for Innovative Cancer Control Project and powerfully advancing research aimed at practical application of cancer treatment including innovative diagnosis and treatment from the latter half of the application stage to clinical stage based on the Comprehensive 10-Year Strategy for Cancer Research.

MHLW is continuing prior strategic cancer research and is promoting the development of innovative therapies that either use genome information including mutation of cancer-related genes or restrict and eradicate cancer stem cells, and that mainly target orphan and refractory cancers. Cancer vaccine therapies are rapidly advancing as a fourth type of therapy, following surgical operations, radiation therapies and chemotherapy. Therefore, MHLW is promoting high-quality, non-clinical trials and international-level, doctor-centered clinical trials for drug development, mainly for refractory and/or orphan cancers, by taking advantage of Japan's rich history of such studies. These studies include those on cancer vaccine therapies, molecular target drugs (such as antibody drugs), nucleic acid medicines and cancer peptide vaccines. This includes methods for effective cancer pain evaluation, advanced information communication and palliative care quality assessment. The goal is to improve treatments for physical pain, cancer-specific pain, depression and anxiety, psychological and mental pain, and social distress, including work and financial problems.

National Institutes for Quantum and Radiological Science and Technology (QST) is promoting research on heavy-ion cancer therapy, which is expected to be a breakthrough therapy for refractory cancers. Efforts

will be made to disseminate its use domestically and internationally. Based on R&D performed by QST, heavy-ion cancer therapy facilities were installed in Hyogo, Gunma, Saga and Kanagawa prefectures for medical treatment. In the field of molecular imaging, QST is promoting development of radioactive drugs including PET probes[1] and biometric devices, research regarding application to Targeted isotope (radionuclide) therapy that is expected to be next-generation therapy using pathological diagnosis and radioactive drugs, and other projects.

G. Research on Mental and Neurological Disorders

Through AMED, MEXT has been implementing the Strategic Research Program for Brain Sciences (SRPBS), which aims at brain science that contributes to society. The program includes R&D aiming at the support for patients' independence using Brain Machine Interface (BMI) technology and permanent cure of mental and neurological disorders by strengthening coordination of clinical and basic research, and R&D to clarify the brain function principles that support behavior selection and adaptation to environment. Since fiscal 2014, MEXT has been implementing the Brain Mapping by Integrated Neurotechnologies for Disease Studies (Brain/MINDS).

At RIKEN and the JST, under the Strategic Basic Research Program (see Chapter 4 Section 2, 1(2)), and AMED under the Advanced Research and Development Programs for Medical Innovation, research into brain science is also being promoted in the fields of molecular structures, nerve cells, neural networks and other areas.

Through AMED, MHLW has been implementing the Comprehensive R&D Project on Measures for Persons with Disabilities and conducting research aimed at clarification of the developing mechanism of mental diseases and establishment of proper diagnosis and treatment methods. Based on the Comprehensive Strategy to Accelerate Dementia Measures (New Orange Plan) formulated in 2015 and through AMED, the ministry has been conducting research toward R&D of dementia prevention, diagnosis and treatment methods, rehabilitation and nursing care models, etc. and working to spread the outcomes under the Research and Development Project for Dementia.

H. Research on Emerging and Reemerging Infectious Diseases

Through AMED, MEXT is implementing the Japan Initiative for Global Research Network on Infectious Diseases and the Japanese Initiative for Progress of Research on Infectious Disease. The 9 research centers in 9 countries throughout Asia and Africa have been collaborating with the relevant organizations of their countries on epidemiological research that addresses the pathogens of infectious diseases widely suffered by the people of the country, in order to promote the basic study of diagnostic/ therapeutic medications and to develop new technologies that contribute to infection control and prevention, and to diagnosis and treatment. Based on the "Action Plan for Strengthening Measures on Emerging Infectious Diseases (February 2016)" decided at the ministerial meeting for measures against emerging infectious diseases, "National Action Plan on Antimicrobial Resistance (AMR) (April 2016)" and "Involvement in the Development of the Laboratory of the Highest Biosafety Level (BSL4) of Nagasaki University (November

1 Radioactive drugs emitting a very small amount of radiation are used for PET examination to make a picture of radiation distribution in a living organism for diagnosis of the cause, conditions, etc. of Alzheimer and other diseases.

2016)," the ministry has been providing support for research by BSL4 facilities and other infectious disease research centers and conducting target search of drug seeds against pathogens, etc. of high pathogenicity with the aim of discovery of innovative medicines against infectious diseases.

Through AMED, MHLW is also conducting research into cell culture-based vaccines and intranasal vaccines, so that simpler and more effective vaccines can quickly be provided to people to contain novel flu pandemics. With particular concern for preventive inoculations that are an important means to fight infectious diseases, MHLW is researching the evaluation of medical safety and economic efficiency, helping the vaccination administration. MHLW is working on the development of proper diagnostic techniques, treatment strategies and preventive methods that facilitate the necessary administrative responses. In the field of novel influenza, MHLW is also conducting research into cell culture-based vaccines and intranasal vaccines, so that simpler and more effective vaccines can quickly be provided to people to contain novel flu pandemics.

I. Research on intractable diseases

MHLW, through AMED, has been implementing the Rare/Intractable Disease Project of Japan *in cooperation with MEXT*. Toward overcoming intractable diseases, the project supports research in areas where research is not making progress due to a small number of patients. The project aims to elucidate pathologic conditions, while at the same time promoting development of new effective remedies and expansion of application of existing drugs, etc. in an integrated manner.

J. Promotion of utilization of health information taking advantage of ICT

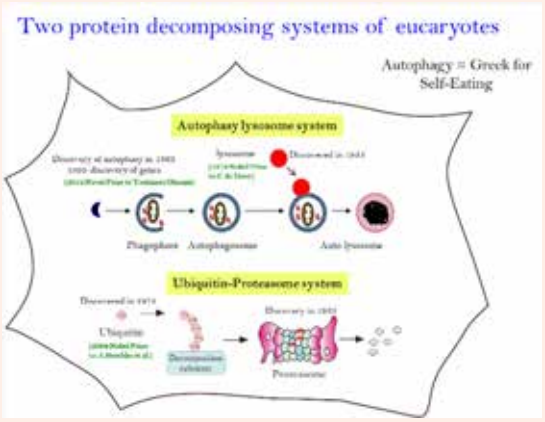
Ministry of Internal Affairs and Communications (MIC) has been using cloud technology to develop regional health information networks (EHR[1]) that enable bi-directional and standards-based connection of multiple disciplines and conducting demonstrations toward construction of an infrastructure for interconnection of EHRs across the country. Through AMED, MIC is also developing concrete service models of a system where users can manage their own medical and other data throughout their lives in chronological order and use the data for multiple purposes (PHR[2]) as well as information coordination technology models across services, and conducting research toward development of a health guidance planning model using AI. Furthermore, the ministry is also implementing research toward development of endoscopes using 8K technology, construction of an AI diagnosis support system utilizing high definition image data, for example. In the field of public administration, MIC has been promoting efforts to improve public services by utilizing ICT across Japan. MIC is also studying and verifying data items, data links and linkage methods for facilitating data linkages among public service authorities through cloud computing services.

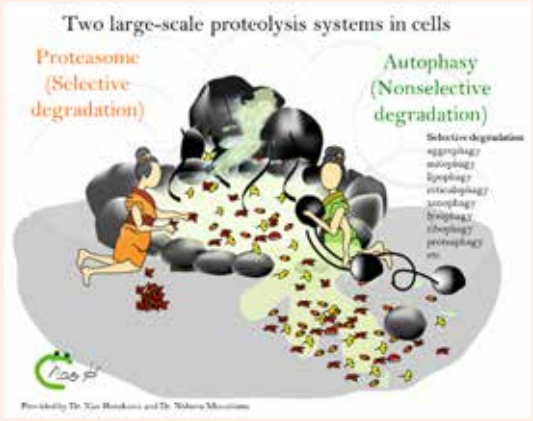
1 Electronic Health Record
2 Personal Health Record

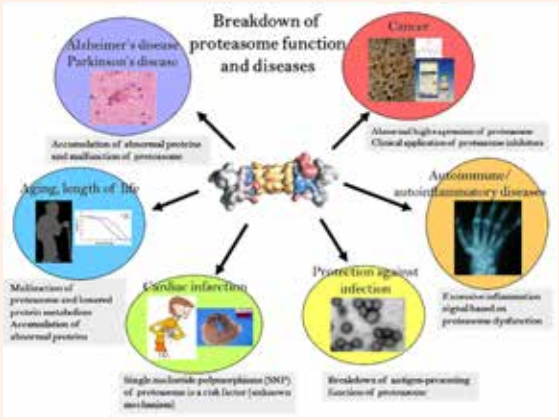
Column 2-5

Establishing the Japan Medical Research and Development Awards

Japan Medical Research and Development Awards were established in FY2017 to praise great contributions to promotion of R&D in the medical field with the aim of obtaining higher interest and understanding of the citizens while increasing incentives for researchers. The Prime Minister's Award was presented to Keiji Tanaka, Chairperson of the Tokyo Metropolitan Institute of Medical Science. He discovered proteasome that degrades proteins. The findings pioneered in developing carcinostatic agents including molecular target drugs. Six awards including the Prime Minister's Award recognized 12 individuals and groups.







Functions of protein decomposing material "proteasome" and its contribution to the development of carcinostatic agents

Provided by: Keiji Tanaka, Chairperson of Tokyo Metropolitan Institute of Medical Science

(2) Building infrastructure for sustainable cities and regions

A. Compact and functional town development

In response to the diversifying living needs of the people, the National Institute for Land and Infrastructure Management is conducting "development of urban structure analysis and evaluation techniques based on the diversifying living support functions" and other research.

B. Research on transportation systems

The Comprehensive Strategy on Science, Technology, and Innovation determines the government's direction of the advanced road transportation system and indicates the policy to promote technology development in the field toward its early realization. With the SIP automated driving system, the Cabinet Office is promoting R&D with focus on five fields: dynamic map necessary for automated driving, HMI[1], information security, reduction in pedestrian accidents and next-generation urban transportation. In October 2017 a large-scale experiment tests started in succession to identify issues and realize early commercialization. In December 2017, possibilities and technical problems of automatic driving of bus were examined on real traffic environment with relatively heavy traffic in an urban area of Okinawa's main island. In addition, international workshops and citizen dialogs[2], etc. have been held to promote international cooperation and standardization and to understand the public's demands, anxieties, questions, etc. concerning automated driving.

Toward realization of safe and secure autonomous mobility systems, MIC has been conducting R&D of technologies for real-time exchange of large-volume data such as a sophisticated map database among vast numbers of moving bodies driving at various velocities via radio with limited transmission capacity. The National Police Agency (NPA), MIC and MLIT have been promoting efforts to introduce and advance driving safety support systems that rely on vehicle-to-infrastructure and vehicle-to-vehicle communications.

In FY 2017, National Research Institute of Police Science (NRIPS) of National Police Agency (NPA) promoted research on an analysis technology using a recording device concerning traffic accidents of vehicles with driver support systems.

MLIT has also been enhancing R&D that helps to improve the safety of railway traffic, including developing platform screen gates that are available to various train door positions relative to the platform and help reduce construction cost.

MPAT has been conducting R&D of technologies pertaining to vessels and use of the oceans using the technologies as well as electronic navigation. In this field, the institute has been implementing research that helps to realize a safe and secure society. Specifically, for the purpose of ensuring the safety of marine transportation, this institution is formulating safety regulations that are socially feasible and that help to substantially reduce accidents at sea. Research is also being conducted on promoting modal shifts, increasing the efficiency of maritime transportation for better logistics and developing transportation systems.

---

1 Human Machine Interface

2 Two-way communication to hear expectations and concerns of general public concerning automated driving and reflect them in R&D activities (two sessions in FY2017)

In the field of electronic navigation, the Institute has been conducting R&D including "advancement of air traffic management through trajectory-based operation," "advancement of airport operation," "optimization of air traffic by utilization of onboard information" and "information sharing among parties concerned and advancement of aircraft flight." The aim of the R&D is to contribute to expansion of air traffic capacity, improvement of the convenience of air traffic, improvement of aircraft flight efficiency and reduction in environmental impact of aircraft, while improving the safety of air traffic.

The National Traffic Safety and Environment Laboratory, National Agency for Automobile and Land Transport Technology is responsible for the following: preventing accidents involving vulnerable road users; research on technologies for ensuring the safety of land transportation including the promotion of the development and practical application of next-generation heavy vehicles; testing and research of technologies for environmental conservation; conformity inspection regarding technological standards of automobiles; and the verification of technological requirements for automobile recalls.

C. Construction of a comprehensive life care foundation system in the communities

For the purpose of clinical applications and life support, MEXT and MHLW are working to develop BMIs that can decode information in the brain in non-invasive or minimally invasive ways, to treat, recover and complement physical functions.

In support of disabled people's independence and participation in society, MHLW has been implementing the Project for Development and Promotion of Equipment to Support Independence of Persons with Disabilities. They seek to develop convenient support apparatuses that can be used easily by disabled people, as per their needs.

METI is promoting a project to provide support to private business operators who are engaged in R&D on welfare apparatuses. To facilitate the practical application of robot care devices in needed areas, METI has been implementing the Project to Promote the Development and Introduction of Robotic Devices for Nursing Care. The ministry is supporting the development on robotics technology by private businesses that address the needs of the elderly and care service personnel.

MLIT has developed technologies for creating and updating indoor 3D maps that form a new social foundation necessary to support people's moving and activities and technologies for outdoor, indoor and outdoor-indoor seamless positioning. The ministry also developed indoor 3-D map data specifications (draft) and technical standards for outdoor-indoor seamless positioning.

Toward construction of a universal society where everyone including the elderly and people with disabilities can engage in activities freely without stress, MLIT developed outdoor-indoor seamless digital maps including information on inclinations and steps for the area from Shin Yokohama Station to the International Stadium Yokohama (Nissan Stadium) and conducted demonstration tests of a navigation service that shows stepless routes.

(3) Extending service life for efficient and effective infrastructure

Concerning the research topic of "infrastructure maintenance, renovation and management technologies" under SIP, the Cabinet Office considers it important that the needs for maintenance be matched with the seeds of technological development. By translating new technologies into practical applications and by

elevating the level of maintenance and management at low cost through preventive maintenance, the Cabinet Office aims to uphold high standards of maintenance and management for important domestic infrastructure. It is intended that the technologies used for this purpose help create an attractive and sustainable market for infrastructure maintenance and management. The Cabinet Office also promotes the export of infrastructure maintenance and management technologies.

MLIT and METI have promoted the development and introduction of robots to maintain social infrastructure and implement anti-disaster measures more effectively and efficiently. METI is implementing the System Development Project to Solve Social Problems for Infrastructure Maintenance and Renewal to develop robots that conduct inspections and surveys in the priority fields and monitoring technologies that enable accurate grasp of the conditions of infrastructure (sensors, imaging, etc.).

MLIT is promoting i-Construction where ICT is used in all construction production processes from investigation/survey to design, installation, inspection, maintenance and renewal. The aim is 20% improvement of productivity in construction sites by FY2025.

For promotion of i-Construction, National Institute for Land and Infrastructure Management (NILIM) is conducting the following research: development of 3D models for data distribution, development of procedures/standard proposals for work progress control/inspection using ICT for various types of works, "research on improvement of construction productivity with full utilization of ICT" to develop methods for central management of information useful for maintenance/management on a 3D model.

In cooperation with other MLIT departments and agencies, NILIM has been developing technologies for the following: road structure maintenance; more efficient maintenance of sewerage pipelines and sewage treatment systems; the maintenance of river structures; utilization of existing buildings; the maintenance and service life prolongation of port facilities; and efficient transportation of marine containers, in order to ensure continued safe use of existing housing and social capital stock through more efficient and advanced inspection, repair and renewal.

Public Works Research Institute has been working on the development of: methods contributing to an effective (efficient, advanced) maintenance cycle of existing structures (bridges, pavements and management facilities); methods for renewal/construction of structures, which enables maintenance and long service life in accordance with the management level for bridges, civil engineering structures and tunnels, and; cross-cutting (roads, rivers, harbors, fishing ports and agriculture) technologies and systematization for maintenance and renewal of infrastructure susceptible to frost damage , complex deterioration and other damages.

MPAT has been working on: enhancement of functions of airports in the Tokyo Metropolitan area by conducting R&D pertaining to improvement of safety and maintenance efficiency of airport infrastructure including runways; technology development regarding inspection and monitoring of coastal zone infrastructure supporting the economic/social activities of the country, and; research contributing to maintenance efficiency and reduction in lifecycle cost.

NIMS has comprehensively conducted R&D in the material field, in which Japan excels, for technologies and new structural materials to inspect, diagnose, repair and upgrade infrastructure with the aim of extending the service life and enhancing the earthquake resistance of the social infrastructure.

Table 2-3-2 Major policies for the realization of sustainable society in response to super aging and population decline (FY2017)

Ministry/ Agency	Implemented by	Project
MEXT	AMED	Grants for promoting the development of medical and health care research
MHLW	AMED	Project for comprehensive promotion of practical application of medical technologies
		R&D on dementia
		Development of infrastructure for promotion of clinical study on regenerative medicine
		Development of Clinical Genomic Information Integrated Database
METI	METI/ Agency for Natural Resources and Energy (ANRE)	Development of Medical Devices and Systems for Advanced Medical Services
		Medical-engineering collaboration business promotion project
	AMED	Project to Promote the Development and Introduction of Robotic Devices for Nursing Care
MOE	MOE/ National Institute for Environmental Studies/ National Center for Child Health and Development/ regional centers s (universities in 15 regions nationwide)	Japan Environment and Children's Study (JECS)

3 Improving competitiveness in manufacturing and value creation

(1) New manufacturing systems

A. Construction of a platform for supply chain system

Construction of a new platform to integrate engineering system chains and production process chains will promote data utilization, improve productivity and create new added values.

In an effort to promote creation of the platform, METI is supporting creation of advanced cases and developing compatible formats for sharing data of various machines and equipment. For small and medium manufacturers facing challenges in data utilization, METI has started to develop consultation centers to train and dispatch specialists who propose improvement plans and technologies tailored to each challenge.

In order to maintain and strengthen the international competitiveness of our maritime industry, MLIT has been promoting technology development for productivity improvement of the industry through efficiency improvement and advancement of ship operation, shipbuilding/shipboard design and production by utilizing information communication technologies including IoT and big data. The ministry is also advancing discussions on roadmap development toward practical application of automatic navigating vessels.

Since October 2017, MLIT has been promoting development and spread of advanced vessels under the System to Authorize Advanced Vessel Introduction Plans.

The National Institute of Information and Communications Technology (NICT) is conducting pioneering R&D on brain activity measuring technology to enable exploration of latent needs based on brain information.

B. Development of innovative production technologies

In order to provide high-performance and high-quality products promptly and flexibly responding to diverse user needs, the Cabinet Office is developing innovative production technologies including 3D printers that process complex shapes at high speed and high accuracy.

METI is implementing the 3D printer technology-based manufacturing innovation program. Under this program, fundamental development is conducted for three-dimensional laminating molding technology suitable for manufacturing of high value-added parts, etc. (increasing speed, precision, functions, etc.) taking advantage of materials, machine control and other technologies where Japan is strong.

METI is also implementing "the project for development and practical application of 3D printer molding technology toward energy-saving manufacturing process." The project aims to establish new energy-saving manufacturing processes using the three-dimensional laminating molding technology before the rest of the world through obtaining experimental proof by quality confirmation, which a challenge for full-fledged introduction of the technology, and through development of optimal molding conditions and quality assessment methods for molded objects.

(2) Integrated materials development system

A. Construction of highly reliable materials database

For strengthening of the international competitiveness of our materials industry, the government is building a materials development system by merging numerical simulation, theories, experiments, analyses and data science. The government is promoting consolidation and database compilation of reliable materials data held in industry, government and academia for the system construction.

B. Establishment of materials development technologies utilizing databases

As part of the program to support establishment of innovation hubs, the JST is promoting the MI²I: Materials Research by Information Integration Initiative, under which computer and data sciences are used for the short-term development of materials with innovative functions. Under this program, NIMS that is a central organization of materials study works as the hub to gather human resources from industry, academia and governments to advance database building and merging with data science. At the same time, the JST is encouraging participation of a broader range of companies and working on implementation of new material designs including groundbreaking magnets, batteries and electric heat control.

Table 2-3-3 Major policies for strengthening of the competitiveness of monozukuri/kotozukuri (FY2017)

Ministry	Implemented by	Project
METI	METI	Demonstration project for robot introduction
	NEDO	Project for development and practical application of 3D printer molding technology toward energy-saving manufacturing process

Section 2 Ensure Safety and Security for Our Nation and its Citizens and a High-quality, Prosperous Way of Life

In order to ensure safety and security for our nation and its citizens and a high-quality, prosperous way of life, it is necessary to work toward disaster prevention, mitigation, and national resilience, as well as to ensure comfortable living environments and occupational health for citizens. In addition, it is essential to appropriately deal with changes in the national safety and security situations and the occurrence of crime, terrorism, and cyber attacks. We are working on science and technology innovation to address these issues.

1 Addressing natural disaster

(1) Improvement of prevention capabilities

Under the Project to Improve Comprehensive Resilience with Focus on the Tokyo Metropolitan Area, MEXT has been building an ultra-high density seismic observation system in public-private collaboration by integrating seismic observation data held by government agencies, local governments, private companies, and others. The ministry is also collecting sensor information concerning the collapse margin of structures including structural members (piping, ceiling, etc.) by using a 3D Full-Scale Earthquake Testing Facility (E-Defense) to develop big data that will contribute to integrated public-private disaster response, business continuity, disaster prevention actions by individuals, etc. for maintenance of urban functions.

MLIT has been developing and operating the Nationwide Ocean Wave Information Network for Ports and Harbors (NOWPHAS) in mutual cooperation with MPAT and other research institutions. Data on waves and tidal levels observed across Japan are collected through this network, and details are published on MLIT's website in real time.

NILIM has been conducting research including the following: (1) Visualization of flood risk for appropriate use of river information for evacuation behavior, (2) method for high-accuracy prediction of sediment disaster using real-time observation/monitoring data, (3) measures for extremely severe disasters, such as landslides and urban flooding due to sudden torrential rainfall, (4) the development of strategic flood mitigation methods that are incorporated with urban development and that address the needs posed by climate change, (5) evaluation criteria of evacuation support technologies for the elderly and people with disabilities in apartment buildings at the time of a disaster, (6) renovation of equipment, etc. to ensure health and safety of evacuees in shelters, (7) methods for safety/use performance evaluation of buildings afflicted by fires induced by an earthquake, (8) "the creation of disaster-resistant towns," including the development of buildings that can be continuously used immediately after an earthquake, (9) advancement of tsunami and high-tide observation technologies to improve the safety of harbor areas, and (10) speedy inspection and restoration of airport pavement at the time of a disaster.

Public Works Research Institute is working on technology development to reduce damage of flood disasters that have become extreme in recent years and damage of tsunami and sea level rise, prevent and mitigate sediment disaster caused by sudden natural phenomenon, and reduce damage of snow/ice disaster caused by extreme weather.

The Building Research Agency is conducting technology development to ensure the structural safety of buildings, thus contributing to prevention of damage/collapse due to natural disasters and ensuring

continued use of buildings.

Towards early recovery and reconstruction after a major earthquake, MPAT is conducting research on forecasting earthquake- and tsunami-related deformation and performance degradation for structures in coastal areas and the areas behind them, and on improved safety and reliability for facilities in coastal areas.

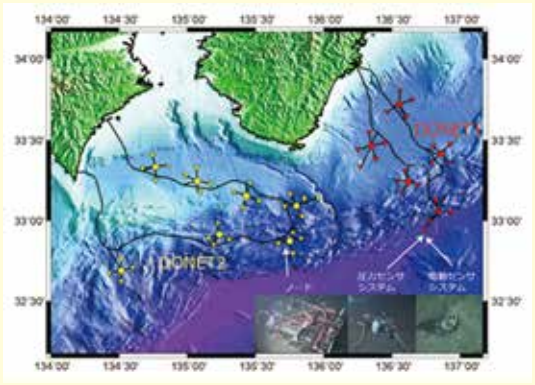
(2) Improvement of predictive capability

Under the Headquarters for Earthquake Research Promotion (Director: the Minister of MEXT; Hereinafter: Earthquake Headquarters), administrative agencies are working in close cooperation on seismological investigations and research.

Considering that the long-term evaluations of the probability and scale of earthquakes conducted by the Earthquake Headquarters did not cover massive multi-segment earthquakes such as the 2011 Tohoku Region Pacific Coast Earthquake, and also in light of the Kumamoto Earthquake, publication methods have been reviewed and long-term evaluation has been made public sequentially.

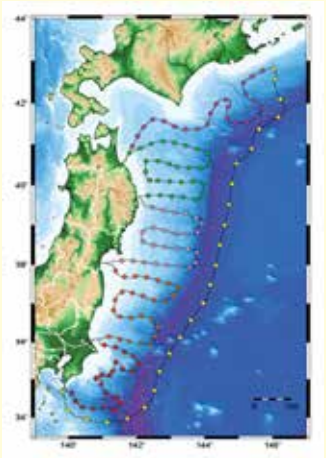
MEXT has conducted investigation and research into potential earthquakes which may cause tremendous social and economic damage under the Research Project for Compound Disaster Mitigation on the Great Earthquakes and Tsunamis around the Nankai Trough Region for Nankai Trough earthquakes. In the Project for Investigations of Earthquakes and Tsunamis in the Sea of Japan, controlled-source surveying and investigations of tsunami deposits were conducted to advance research on an earthquake source fault model and a tsunami source model that would be applicable to the Sea of Japan and its coast.

Figure 2-3-4 **Dense Oceanfloor Network System for Earthquakes and Tsunamis (DONET)**



Source: MEXT

Figure 2-3-5 **Seafloor observation network for earthquakes and tsunamis along the Japan Trench (S-net)**



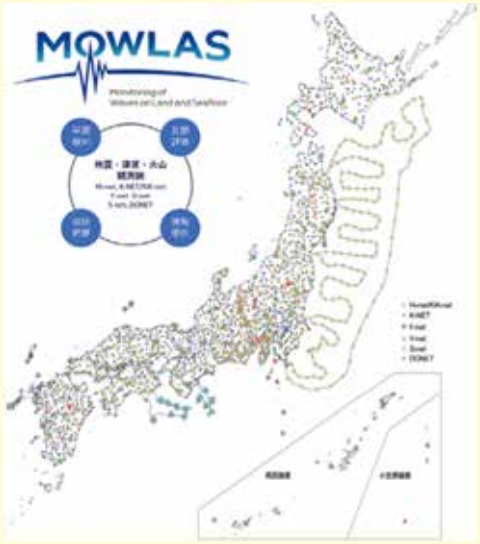
After the Great Hanshin-Awaji Earthquake, comprehensive earthquake observation networks were densely built in land areas. Although several sea-area observation networks have been built, there are far fewer observation points in these networks than in land-based observation networks. Accordingly, MEXT is operating the Dense Ocean floor Network system for Earthquakes and Tsunamis (DONET) that is a dense submarine network equipped with seismometers and hydraulic gauges for real-time seismic

observation in the hypocentral region of the assumed Nankai Earthquake (Figure 2-3-4). Furthermore, off the Pacific Coast of Tohoku where large aftershocks and tsunamis are likely to occur, the Seafloor Observation Network for Earthquakes and Tsunamis along the Japan Trench (S-net) has been operated to directly detect earthquake and tsunami to contribute to accurate and prompt communication of disaster information (Figure 2-3-5).

In the field of volcanology, the FY2016 Integrated Program for Next Generation Volcano Research and Human Resource Development was launched to promote integrated research of "observation, prediction and measures" in coordination and jointly with other fields including geochemistry in response to the eruption of Mt. Ontakesan in 2014. At the same time a consortium for human resource development in volcanology was formed to strengthen cooperation among universities. The consortium has been providing systematic education programs linked to cutting-edge volcano research.

NIED is observing various tremors ranging from feeble tremors imperceptible to the human body to strong tremors causing big damage by using about 1,900 high-performance and high-precision seismometers covering the entire area of Japan evenly and densely. It operates about 200 seismometers and tsunami meters in sea area and started full-scale operation of Monitoring of Waves on Land and Seafloor (MOWLAS) in November 2017. MOWLAS is an earthquake, tsunami and volcano observation network covering all land and sea areas of Japan, including the fundamental volcano observation network (V-net) for 16 volcanoes in Japan. NIED is advancing research and implementation of real-time prediction of earthquake and tsunami as well as observation and prediction of volcanic activities by using MOWLAS and will continue to provide observation data to Japan Meteorological Agency. Railway companies also started to use the data (Figure 2-3-6).

Figure 2-3-6 Monitoring of Waves on Land and Seafloor (MOWLAS)



Source: MEXT

In addition, NIED is also conducting research on highly accurate rainfall prediction and sediment, storm and flood damage prediction based on multi-sensing and research contributing to reduction of damage caused by natural disasters including coastal disaster. Furthermore, toward creation of new innovations of science and technology for disaster prevention, NIED launched formation of "an innovation hub to realize active reduction of weather hazard toward aggressive disaster prevention" with the goal of mitigating/preventing weather hazards and generating positive ripple effects for industry. In order to solve regional disaster prevention problems, NIED developed censors for snow damage and sediment disaster and installed them in model areas. It also started a demonstration experiment to collect data and provide information using IoT technology in cooperation with local stakeholders and producers. For promotion of

R&D on lightening risk prediction based on comparative analysis with MP radar[1] data, etc., NIED started continuous observation of lightening using a lightening discharge path 3D observation system in the Tokyo metropolitan area.

JMA in cooperation with MEXT is collecting, processing and analyzing data of the fundamental observation/research network for earthquake, using the results for disaster prevention information, and providing them to the Earthquake Research Committee Headquarters for Earthquake Research Promotion and others. JMA also developed the Automatic Hypocenter Determination Method (PF method) and introduced the method in April 2016. For earthquake early warning, JMA developed new methods – IPF method[2] and PLUM method[3] – in preparation for future multi-segment earthquakes and massive earthquakes for which the risk has been widely recognized after the off the Pacific Coast of Tohoku Earthquake. IPF and PLUM methods were introduced in December 2016 and March 2018 respectively.

The Meteorological Research Institute (MRI) researches the following topics: the development of real-time scale estimation of tsunami/earthquake to mitigate damage by tsunamis, and tsunami forecasting based on offshore tsunami monitoring data; technologies for seismic intensity estimation that help improve the accuracy of earthquake early warnings; research of technologies for monitoring and analyzing crustal movements that help improve the accuracy of grasping of changes in fixation between plates along the Nankai Trough, and development of a monitoring method to advance volcanic activity assessment and prediction.

To collect geological information useful for disaster prevention, the National Institute of Advanced Industrial Science and Technology (AIST) conducts deposit surveys of active faults and tsunami sediment, conducts geological surveys of active volcanoes, and publishes the results of these surveys. In order to elucidate the fault distribution and the history of fault activities, its geological surveys included 6 major fault zones nationwide on land and in the near shore sea including the Futagawa and Hinagu fault zones that were involved in the Kumamoto Earthquake in 2016. AIST's database on tsunami deposits was released to the public in October 2015. Data collected in the each partial areas in Mie and Kochi prefectures, were added to the database. For short-term predictions of Nankai Trough Great Earthquakes, AIST continued to operate its integrated groundwater observation points to measure groundwater levels (water pressures), groundwater temperatures, crustal strains and seismic waves. Concerning the volcanoes where eruption activities were observed (Shinmoedake (Kirishimayama) and Kusatsu-Shiranesan), AIST conducted field investigations and analyzed volcanic products. The investigation and analysis results were used for material scientific studies that are expected to help understand the ongoing eruption activities and predict changes in these activities.

JAMSTEC is developing and deploying technologies to grasp changes in the fixation of plate boundaries directly above hypocentral regions continuously and in real-time using devices for long-term observation in boreholes of the deep sea drilling vessel "CHIKYU" and DONET. JAMSTEC is also conducting high-accuracy survey of the sub-seafloor structure of the sea areas with high urgency and importance with focus on segment borders of the Nankai Trough, which are important for assessment of linkage of the Tokai,

1 Multi-parameter radar that can simultaneously transmit / receive two types of radio waves (horizontally and vertically polarized waves)
2 Integrated Particle Filter method
3 Propagation of Local Undamped Motion method

Tonankai and Nankai earthquakes. A more realistic model will be built by incorporating the survey and observation results to contribute to more accurate crustal movement and tsunami simulations.

Geospatial Information Authority of Japan (GSI) engages in R&D on technologies for the observation and analysis of crustal and plate movements through continuous GNSS[1] observation at electronic reference stations[2], through Very-Long-Baseline Interferometry (VLBI[3]) and through SAR4 Interferometry[4]. Detailed monitoring of crustal movements in and around volcanoes has been implemented through integrated analysis of GNSS volcanic observation data, which have been collected in and around volcanoes by JMA, NIED, AIST, the Hot Springs Research Institute of Kanagawa Prefecture and the Earthquake Research Institute of the University of Tokyo.

The Japan Coast Guard (JCG) has been advancing observations of crustal movements on the sea floor by means of GPS and echo ranging, as well as advancing surveys of submarine topography and active faults and announcing the observation results from time to time.

(3) Improvement of response capabilities

Natural disasters have been expanding in scale, so damage caused by them has been exacerbating and Japanese society has become increasingly vulnerable to these disasters. In light of these situations and the concept of disaster resilience, the Cabinet Office has been promoting R&D on technologies for a disaster-resilient information system under the SIP Program "Enhancement of Societal Resiliency against Natural Disasters." Resilient infrastructure minimizes disaster damage, thereby helping communities to withstand and rapidly recover from shocks and helping affected people to regain control of their lives. The "disaster information system for resilience" is based on advanced technologies for predicting, preventing and responding to disasters as well as for sharing information, and it can be used to improve the disaster prevention and mitigation capabilities of the national government, local governments, businesses and the public. At the time of Northern Kyushu Torrential Rain in July 2017, disaster response support was provided by using this system to integrate disaster-related data of relevant ministries and agencies.

MIC has been conducting R&D on ICT for improving the disaster-resistance of information and communications facilities, and for collecting data on damage at times of disaster. Having learned lessons from these problems, MIC has vigorously applied its research results, such as a communication system that can be carried in disaster-stricken areas for emergency restoration of communications (a movable and deployable ICT resource unit) in communities in Japan and worldwide.

In the Research Project for Supporting Regional Disaster-prevention Measures, MEXT developed a database based on research for disaster prevention measures from universities nationwide. Additionally, the utilization of research results in the formulation of regional anti-disaster measures was promoted.

NIED conducts research on the development of systems to share and utilize information of various natural disasters, and has been demonstrating them and providing information for public disaster response

1 Global Navigation Satellite System

2 There were 1,300 electronic reference stations across the country as of the end of March 2018.

3 Very Long Baseline Interferometry: an advanced technique that utilizes radio waves from deep space as far as billions of light years away for precisely measuring the distance between two radio telescopes situated thousands of kilometers away from each other within a tolerance of a few millimeters.

4 Synthetic Aperture Radar: a technique for using an artificial satellite for obtaining information about the evolution and state of earth's surface.

based on its responsibility as a designated public institution.

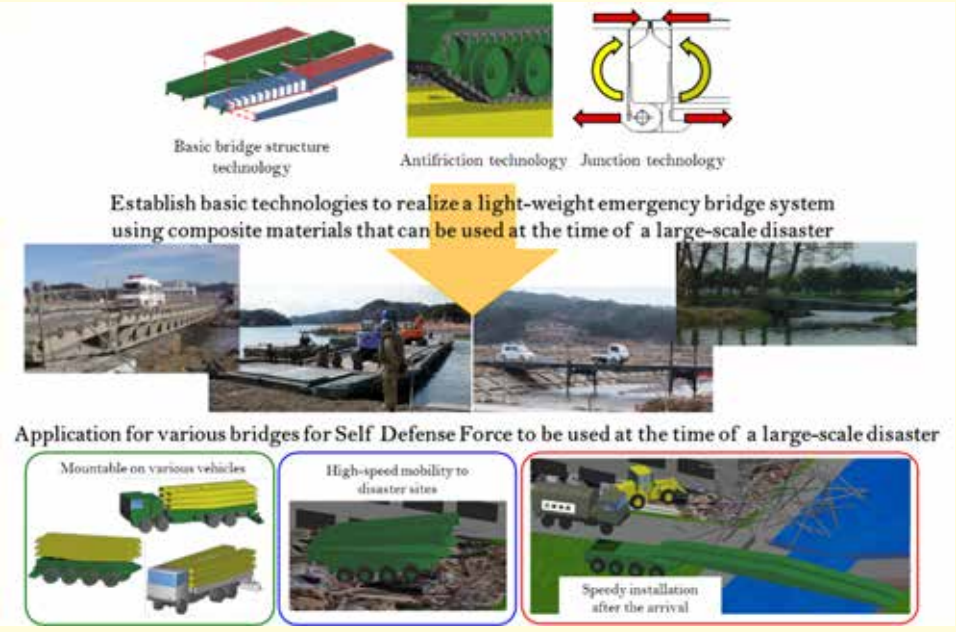
NIED conducted investigation and analysis to determine the cause of the avalanche disaster that occurred in Nasu town of Tochigi in March 2017. NIED found out that snowfall caused by a cyclone off the south coast of Japan was a major factor of the avalanche and held seminars on snow and avalanches to prevent accidents in the future.

As regards the Northern Kyushu Heavy Rain in July 2017, NIED examined the predictability of precipitation, mechanism of sediment disaster, and effects of land form, geological features and soil on the volume of sediment run-off. In response to this heavy rain, NIED used the Sharing Information Platform for Disaster Management (SIP4D) and NIED Crisis Response Site (NIED-CRS), which are results of R&D on disaster information sharing and dissemination, to support information sharing and utilization.

At the time of eruptions of Mt. Kirishima (Shinmoedake, October 2017) and Kusatsu-Shirane volcano (January 2018), NIED also supported information sharing and utilization through SIP4D and NIED-CRS. The institute also examined eruption products on the eruption fields and published the results through NIED-CRS. Furthermore, considering the risk of volcanic mud flow by snow melt after the Kusatsu-Shirane eruption, NIED conducted basic field snow survey after the eruption and checked the snow depth and quality around Mt. Shirane.

MOD is conducting research on high-mobility powered suits that enables quick and agile action and travel on uneven ground while reducing weight load on personnel (See Chapter 3 Section 2, 4). In order to quickly secure an alternative means for damaged bridges after a large-scale disaster to support rescue of victims and rapid deployment of restoration teams, NIED has been conducting research for establishment of an emergency bridge foundation technology using light-weight and high-intensity composite materials (Figure 2-3-7).

Figure 2-3-7 Research and trial of components of future light-weight bridges



Source: Acquisition, Technology & Logistics Agency (ATLA)

FDMA's National Research Institute of Fire and Disaster has advanced R&D on a fire-fighting robot system for deployment in the event of disasters at energy or industrial infrastructure sites. These robots feature sophisticated autonomy based on geospatial information technology and ICT, as well as cooperation and coordination among the robots. Thus, they will be able to collect information and discharge fire-fighting water at disaster sites that are accessible only to robots. The institute implemented evaluation tests of the primary experimental models of four types of robots constituting the system at the Fire-Defense Headquarters and started R&D of a system for field deployment based on the test result.

In addition, the NRIFD is conducting R&D of the following technologies: (1) high-accuracy prediction of earthquake damage to oil tank (identification of characteristics of short-period ground motion that is likely to cause damage to the oil tank body, influence of long-period ground motion on individual tanks due to differences in underground structure, etc.); (2) Powerful foam extinguishing technology tailored to the scale of fire, oil type, etc. of oil tank; (3) More suitable assessment of fire risk of highly reactive chemical substances (e.g. water reactive substance, substance prone to ignition caused by heat accumulation) stored or handled in petrochemical complexes) and safety management while firefighting.

In preparation for large-scale spread of fire in built-up area, which is feared after a Nankai mega thrust earthquake or earthquake that hits the Tokyo area directly, the NRIFD has been conducting R&D to advance simulations of urban fire spread, elucidation of the phenomena of fire whirlwinds and flying sparks that expand damage, utilization of the results for evacuation guidance for residents and firefighting activities. In addition, the NRIFD is conducting R&D on improvement of capability to investigate the cause of a fire in order to take effective fire prevention measures, and also launched R&D on effective evacuation from a building. Furthermore, the NRIFD is conducting R&D on search and rescue using image information from above obtained by UAV[1], etc. and a method to remove debris piled up all over the place.

NICT has been promoting R&D on an airborne polarimetric and interferometric synthetic aperture radar system (Pi-SAR2) that can observe the ground surface in disaster-stricken areas as needed, regardless of weather conditions. NICT is also developing the following technologies: disaster-resistant wireless mesh network technologies that will allow local wireless networking even when the communication infrastructure is devastated, and a wireless relay technology that uses aerial drones as virtual communication towers. Together with the municipality, MIC is conducting field demonstration experiments of these technologies.

NILIM included disaster prevention and mitigation in its "disaster prevention, mitigation and risk management" issues to cope with a new stage of climatic changes, such as concentrated and regional heavy rainfall on the rise in recent days and is conducting research into anti-disaster measures for landslide and urban flooding caused by regional heavy rain, and control measures of maximum possible river flooding. NILIM also conducts research on acceleration of initial response after a large-scale earthquake through development of technologies that support elimination of road obstacles, restoration of infrastructure, TEC-FORCE[2] and other activities immediately after the disaster taking advantage of small on-airplane SAR[3] and existing cameras and sensors.

---

1 Unmanned Aerial Vehicle

2 Technical Emergency Control Force: A team organized by MLIT in FY2008 for survey of damage and technical support for afflicted local governments at the time of a large-scale natural disaster.

3 Synthetic Aperture Radar

Public Works Research Institute is developing technologies to support risk management of water disasters in Japan and abroad, and technologies for minimizing damage of a major earthquake to structures and their early restoration

JAXA has been contributing to various disasters monitoring and grasping of the state of disaster using the second Advanced Land Observing Satellite DAICHI (ALOS-2[1]) and other satellites (See Chapter 3 Section 4.)

Table 2-3-8 Major policies for response to natural disasters (FY2017)

Ministry	Implemented by	Project
MEXT	MEXT	Project to Improve Comprehensive Resilience with Focus on the Tokyo Metropolitan Area
		Integrated Program for Next Generation Volcano Research and Human Resource Development
		Operation of a submarine earthquake and tsunami observation network
		Research project on Nankai megathrust earthquake disaster prevention, Sea of Japan earthquake and tsunami research project
		Headquarters for Earthquake Research Promotion
MOD	Acquisition, Technology & Logistics Agency (ATLA)	Research on future light-weight bridge technology

(4) Response to the Great East Japan Earthquake and reconstruction/rebirth

A. Industrial recovery from, and reconstruction after, the Great East Japan Earthquake in the afflicted regions

For the restoration of the offshore marine ecosystem, which was damaged by tsunamis on the Pacific coast of Tohoku, MEXT has established the Tohoku Marine Science Center in collaboration with local municipalities and national ministries. The center has been conducting surveys and other research on the offshore marine ecosystem. The results have been used to draft a local fishery plan and to select the locations of fish farms.

Aiming at revitalizing agriculture, forestry and fishery, which are the main industries in the areas affected by the disaster, at accelerating the restoration and reconstruction of farm and fishery villages, and at fostering new types of agriculture, forestry and fishery that have high growth potential, MAFF has been conducting large-scale empirical research by applying cutting-edge technologies in agriculture, forestry and fishery, analyzing the effects of such technologies and promoting the dissemination of the research results. In doing so, MAFF has established empirical research sites for agriculture at farming villages in Iwate, Miyagi and Fukushima prefectures and has established empirical research sites for fishery at fishing villages in Iwate and Miyagi prefectures. Empirical research topics include land-extensive farming; greenhouse horticulture; and shellfish and fish culture, release and processing.

B. Efforts on compensation for nuclear damage

The purpose of the Act on Compensation for Nuclear Damage (Act No. 147 of 1961) is to protect persons

1 Advanced Land Observing Satellite-2

suffering from nuclear damage and to contribute to the sound development of the nuclear industry by establishing the basic system regarding compensation in case of nuclear damage caused by reactor operation etc. The act concentrates liability for nuclear damage on the nuclear operators and places unlimited liability without fault on them. In order to ensure prompt payment of compensation by the nuclear operators, the act provides an obligation of provision of financial security by nuclear operators and the aid from the government when nuclear damage exceeds the financial security amount, as well as establishment of the Dispute Reconciliation Committee for Nuclear Damage Compensation to ensure smooth and appropriate payment of damages.

Since the accident at the TEPCO Fukushima Daiichi and Daini Nuclear Power Stations (hereinafter: the accident), a number of residents have been forced to live in evacuation shelters or to give up business activities such as manufacturing and sales. It is essential that these victims receive compensation promptly, equitably and appropriately, so that they may return to safe, secure living as quickly as possible. To this end, various measures have been taken for victims of the accident based on the Act on Compensation for Nuclear Damage.

MEXT instituted the Dispute Reconciliation Committee for Nuclear Damage Compensation. The committee has been formulating guidelines to indicate the damaged items that can be classified with certain criteria and the extent of compensation, with the input of local opinions, and it has been reviewing these guidelines as needed. Furthermore, the Nuclear Damage Compensation Dispute Resolution Center has been conducting reconciliation of alternative dispute resolutions while improving its operations and increasing in personnel.

The government approved the revised New Comprehensive Special Business Plan in May 2017 (its change was approved in July of the same year), which made mention of providing prompt and appropriate compensation for nuclear damage by TEPCO and its streamlined management. The government has been providing assistance to TEPCO through the Nuclear Damage Compensation and Decommissioning Facilitation Corporation for providing compensation smoothly.

The Advisory Committee on Nuclear Damage Compensation System (set up in May 2015) of the Atomic Energy Commission under the Cabinet Office studied review of the compensation system and compiled a preliminary draft in January 2018.

Table 2-3-9 Major projects for recovery and reconstruction from the earthquake disaster (FY2017)

Ministry/ Agency	Implemented by	Project
Reconstruction Agency	Reconstruction Agency	Expenses needed for the promotion of R&D on the environment
		Tohoku Ecosystem-Associated Marine Sciences program
		Maintenance for National Universities and Inter-university Research Institute Corporations
		Tohoku Innovative Materials Technology Initiatives for Reconstruction
		Scheme to Revitalize Agriculture and Fisheries in the Disaster Area by Deploying Highly Advanced Technology (Reconstruction Special Account)
		Forest Decontamination Demonstration Project (Reconstruction Special Account)
		Verification of the Radioactive Decontamination of Forests and the Recovery of the Forestry Industry (Reconstruction Special Account)
		Promotion of projects for industry-academia-government collaboration and for regional scientific technology
	AIST	Fukushima Renewable Energy Industry Support Program
	AMED	Grants for promoting the development of medical and health care research
MEXT	MEXT	Expenses for the operation of the earthquake and tsunami observation/surveillance system

2 Ensuring food safety, living environments, and occupational health

(1) Ensuring food safety and security

MEXT publishes the Japanese Standard Tables of Food Composition, which lists the composition of the Japanese diet. As data pooling had been required to address the needs of the modern Japanese diet, MEXT compiled "the Standard Tables of Food Composition in Japan 2015 (seventh revised edition) Supplementary edition 2018" in December 2018. The new table lists a greater variety of foods.

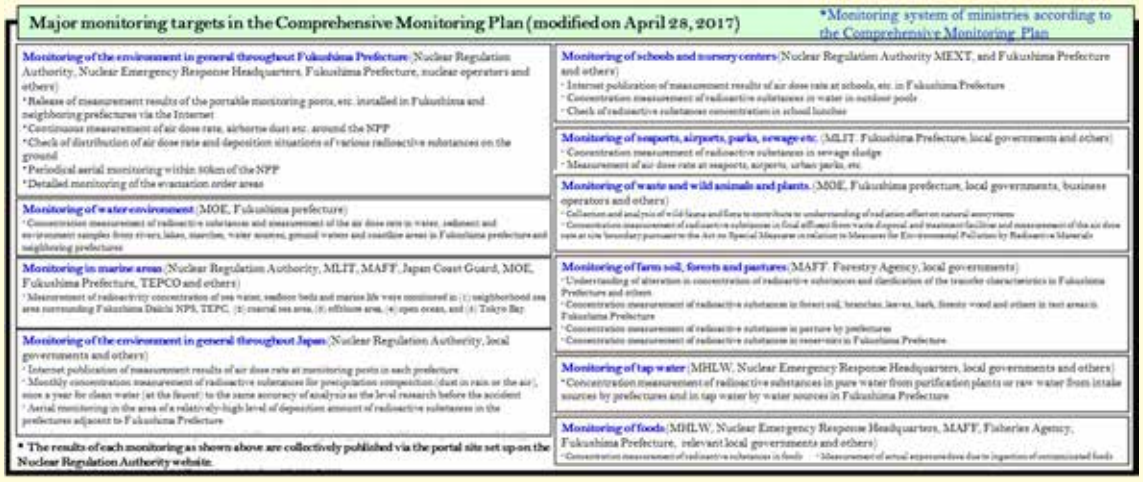
MAFF is working on development of technologies for reducing the risk posed by hazardous microbes and chemicals during the production, distribution and processing processes in order to ensure the stable supply of safe agricultural, livestock and marine products and; the enhancement of accuracy and efficiency of communicable disease control and development of diagnostic methods, with the aim of lowering the risk of spreading of major livestock diseases and thereby reducing farmers' economic losses.

(2) Ensuring safety and security of the living environment

A. Implementation of radiation monitoring

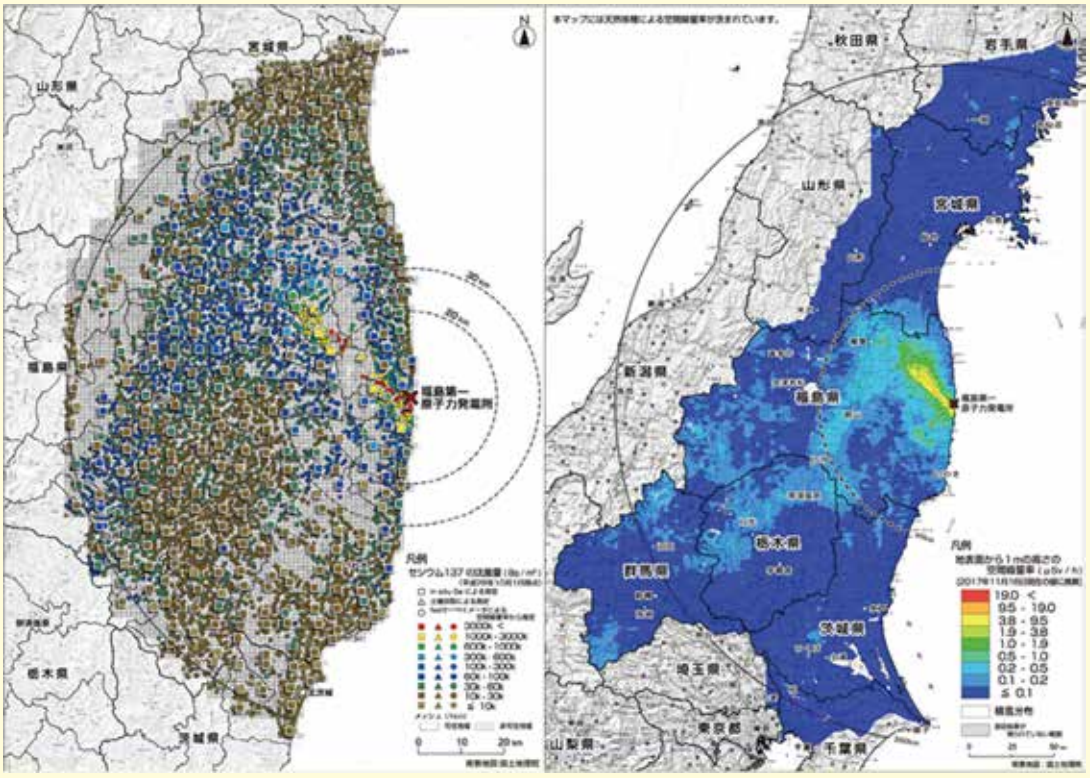
With respect to the radiation monitoring necessitated by the accident at the Fukushima Daiichi Nuclear Power Station of TEPCO, ministries, local municipalities and other authorities are measuring air dose rates at monitoring posts, analyzing radioactive substances in soil in terms of nuclides, analyzing radioactive substances in the water and deposit in rivers and seas, and monitoring radioactive substances in food and tap water. This is being done in line with the Comprehensive Monitoring Strategy (adopted by the Monitoring Coordination Meeting in August of 2011 and revised in April 2017) (Figure 2-3-10).

Figure 2-3-10 Monitoring system implementation by ministries in accordance with the Comprehensive Monitoring Strategy



Source: Nuclear Regulatory Agency (NRA)

Figure 2-3-11 Radioactive substances distribution map



* Cesium 137 soil concentration map (as of October 1, 2016: 66 months after the accident) (left)
* Spatial dose rate map of Fukushima and neighboring prefectures (as of November 16, 2017: 80 months after the accident) (right)

Source: Nuclear Regulatory Agency (NRA)

In FY2017, to clarify the distribution of radioactive substances released as a result of the accident at the TEPCO Fukushima Daiichi Nuclear Power Station, the ministry continued to collate information concerning the distribution of radio cesium and the like (Figure 2-3-11). The ministry also published the results of travel surveys conducted in cooperation with local governments. In addition, the ministry conducted aerial monitoring within and beyond an 80-km circumference from the TEPCO Fukushima Daiichi Nuclear Power Station and announced the air dose rates of the area (Figure 2-3-11). In coastal areas, sea water, seafloor beds and marine life off the coasts of Fukushima, Miyagi and Ibaraki prefectures were jointly monitored by the relevant ministries and local governments in line with the Implementation Guides on Sea Area Monitoring formulated on April 28, 2017.

Air dose rates are measured by a real-time dose measurement system set up in Fukushima Prefecture, using portable monitoring posts set up in the whole of the prefecture and neighboring prefectures and by fixed monitoring posts set up in all prefectures throughout Japan in order to strengthen the nationwide radiation survey system. These measurements are displayed on the website on a real-time basis (Figure 2-3-12).

MAFF conducted surveys on the distribution of radioactive materials in farmland soil to advance efforts to restart farming. These include farmland decontamination.

Figure 2-3-12 Sample of Radiation measurement map

* The system has been managed by the Nuclear Regulation Authority (NRA) since April 2013.
Monitoring information of environmental radioactivity level, Nuclear Regulation Authority: http://radioactivity.nsr.go.jp/ja/

Source: Nuclear Regulatory Agency (NRA)

B. Efforts for measures against radioactive substances

The organizations concerned are working together on development of technology and research and study towards establishing measures to deal with radioactive substances, for the purpose of remediating the environment contaminated by radioactive materials released in the accident at the TEPCO Fukushima Daiichi Nuclear Power Station.

Not only does MAFF develop technologies aimed at the effective and efficient countermeasures on radioactive materials in forests and farmlands, but it also has demonstrated the technologies so far developed. Their results are published swiftly. MAFF is also developing technologies to deal with various post-decontamination challenges, such as technologies for controlling the luxuriant growth of weeds and for controlling soil runoff after the decontamination of agricultural land.

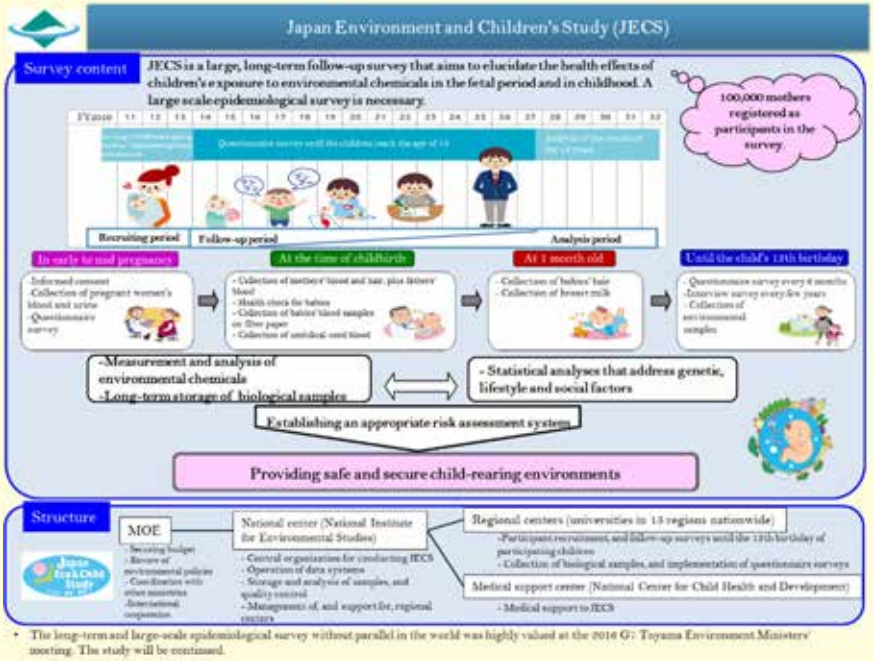
MOE has compiled a strategy for developing technologies regarding the volume reduction and recycling of radioactive substances towards the disposal of soil derived from decontamination within Fukushima Prefecture outside the prefecture. The ministry has also been carrying out a project to verify the effects and safety of technologies that can be utilized for volume reduction and other purposes.

JAEA moved into the research building of the Fukushima Environment Creation Center. In coordination and cooperation with Fukushima Prefecture, the National Institute for Environmental Studies (NIES) and others, JAEA is conducting R&D into technology for measuring radiation doses, research on the behavior of radioactive substances in the environment and R&D on technologies for the volume reduction and recycling of radioactive substances. The aim is to restore environments that were contaminated by radioactive substances released in the accident at the TEPCO Fukushima Daiichi Nuclear Power Station.

C. Efforts to clarify environmental risks to children

In FY 2010, MOE started a large-scale, long-term birth cohort study, the Japan Environment and Children's Study (JECS), by enrolling 100,000 pairs of parents/ children across the country in the study. In this study, blood of mothers, umbilical blood, breast milk and other biological samples of the subjects were taken, preserved and analyzed. Follow-up studies will be conducted using questionnaires, until the children reach 13 years of age to clarify the influences of environmental chemical agents on children's health (Figure 2-3-13).

Figure 2-3-13 Japan Environment and Children's Study (JECS)



Source: MOE

Under JECS, NIES serves as the core center and the National Center for Child Health and Development (NCCHD) serves as the medical support center. NIES develops research plans and analyzes biological samples. The NCCHD provides medical support. Concurrently, regional centers, which are publicly recruited from 15 districts throughout Japan, have been conducting follow-up studies. Based on the results of this study, MOE will re-examine environmental policies. In fiscal 2017, follow-up using questionnaires and detailed investigations were continued, which include collection of environmental specimens and medical examinations covering about 5,000 children chosen from the 100,000 children enrolled in the nationwide survey.

Table 2-3-14 Major policies to ensure food safety, living environment, occupational health, etc. (FY2017)

Ministry	Implemented by	Project
MHLW	Radiation Effects Research Foundation	Expenses required for R&D on technology using radio waves for radio use financial source
	Prefectural governments	Cost for Commissioning Toxic Gas Disability Person Investigation
MOE	Nuclear Regulation Authority (NRA)	Costs for commissioning surveys on the level of radioactivity
		Costs for commissioning surveys on a comprehensive radiation assessment of the marine environment

3 Ensuring Cybersecurity

For the purpose of comprehensively and effectively advancing measures for Cybersecurity pursuant to the Basic Act on Cybersecurity (Act No. 104, 2014), R&D on technologies for Cybersecurity have been

promoted on the basis of the Cyber Security Strategy, which was decided by the Cabinet in September 2015 after deliberations by the Cybersecurity strategy headquarters led by the government.

In August 2016 the "General Framework regarding Security for Safe IoT System" was formulated to study specific measures for promotion of security of IoT systems.

In July 2017 "Cyber Security R&D Strategy" was formulated showing the vision of the future direction of cyber security R&D with evolution of information communication technologies in mind.

In order to protect critical infrastructure supporting the people's everyday life from cyber attacks, the Cabinet Office launched the Cyber-Security for Critical Infrastructure (SIP). Under this program, it is conducting R&D of operation monitoring/analysis and defense technologies including authenticity determination (technology to confirm authenticity and integrity of equipment/software) of control/communication equipment, while promoting R&D activities aimed at strengthening of international competitiveness of critical infrastructure industries and contribution to stable operation of the 2020 Tokyo Olympic and Paralympic Games.

Through the National Institute of Information and Communications Technology (NICT), MIC has been promoting R&D in the field of cyber security. MIC aims to use its technical knowledge on cyber security to train security human resources who have practical ability to handle increasingly sophisticated and complex cyber attacks. To this purpose, the ministry has been promoting initiatives such as practical cyber defense exercise (CYDER[1]) for national administrative organs, local governments, Incorporated Administrative Agencies, important infrastructure businesses and others at the National Cyber Training Center organized in the institute in April 2017.

Table 2-3-15 Major policies for cyber security (FY2017)

Ministry	Implemented by	Project
MIC	NICT	The establishment of the National Cyber Training Center

4 Addressing national security issues

The National Security Strategy (National Security Council/Cabinet decision on December 17, 2013) states: "The advanced technology of Japan constitutes the foundation of its economic strength and defense forces and is also a valuable resource that the international community strongly seeks from Japan. Therefore, Japan should encourage the further promotion of technologies, including dual use technologies, thereby strengthening Japan's technological capabilities."

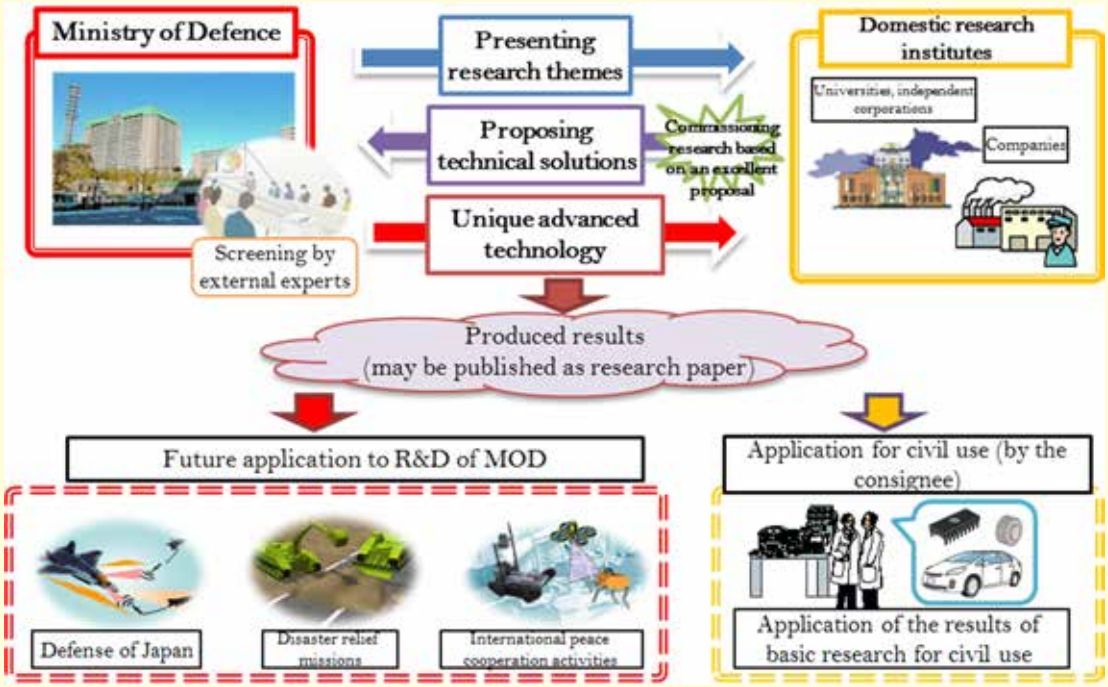
The 5th Science and Technology Basic Plan suggests that "the fruit of science and technology have the potential to make impacts in multiple areas" and "In view of the increasingly challenging environment surrounding national security, in order to ensure the safety and security of the nation and its citizens, it is important to make use of Japan's many outstanding technological strengths." Based on the National Security Strategy and the 5th Science and Technology Basic Plan, it is necessary to promote R&D on technologies necessary to address national security issues in cooperation with relevant ministries and through industry-academia-government collaboration.

1 Cyber Defense Exercise with Recurrence

The Comprehensive Strategy on Science, Technology and Innovation 2017 states that "relevant ministries shall cooperate to strengthen the system to grasp, overview, survey and analyze science and technology trends in Japan and abroad, and discuss cultivation of science and technologies that are expected to be used in various fields, while at the same time enhancing R&D to strengthen technologies contributing to the safety and security of the citizens and the nation" as "priority initiatives." For appropriate management of science and technology information, the strategy states "In order to reinforce prevention of technology information leakage, promote efforts for security trade control including full compliance of the Foreign Exchange and Foreign Trade Act at universities, public research institutes, etc. To this purpose, consider including security control trade in the requirements for government research projects. Considering the risk that research outcomes or technologies could be used for a weapon of mass destruction against the research intention due to the ambiguity of science and technology, the government will support development of a system to ensure appropriate management of sensitive technologies within the organization by universities, public research institutions, etc."

Hoping for future contribution to R&D in the field of defense, MOD launched Innovative Science & Technology Initiative for Security to publicly invite and commission research on advanced civil technologies (Figure 2-3-16) in fiscal 2015. The ministry expanded the initiative in FY2017 and started to foster exploratory research in advanced technology fields where large-scale investments are effective in terms of the budget and research period. The initiative covers basic research and is looking for research that is based on the free thinking of researchers. In order to contribute to broad development of research, all research results may be made public. No secret: including specially designated secrets, will be provided to consignees or no research result will be designated as secret: including specially designated secrets. Results of research conducted under the initiative have been published at conferences and in academic journals.

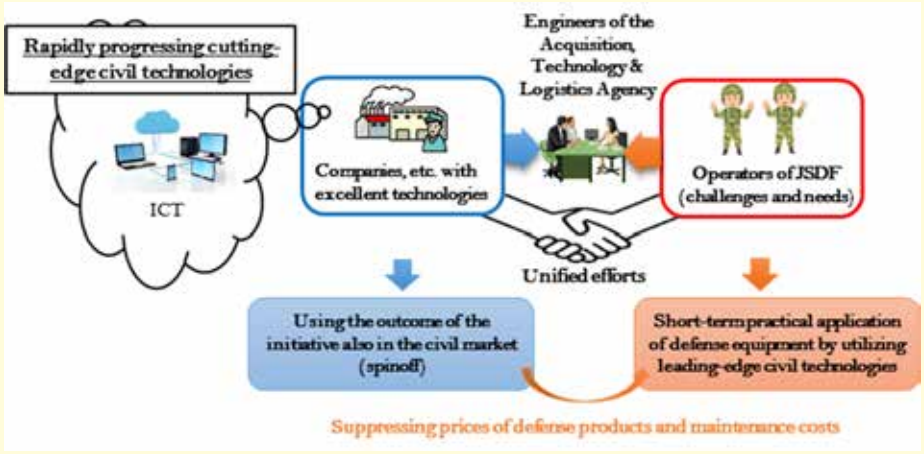
Figure 2-3-16 Outline of Innovative Science & Technology Initiative for Security



Source: ATLA

Since FY2017 Ministry of Defense has been working for practical application of ICT and other civilian technologies that progress rapidly with a short innovation cycle in a short period of time of 3 to 5 years in close collaboration of engineers and operators (Figure2-3-17). Based on the "Fiscal Year 2016 Medium- To Long-Term Technology Outlook" (August 2016, ATLA), the ministry has been promoting R&D for unmanned operation, smart and networking technologies, high output energy technologies and function/performance improvement of existing equipment, which are especially emphasized as advanced technical fields that can be game changers in the national security environment in the coming 20 years.

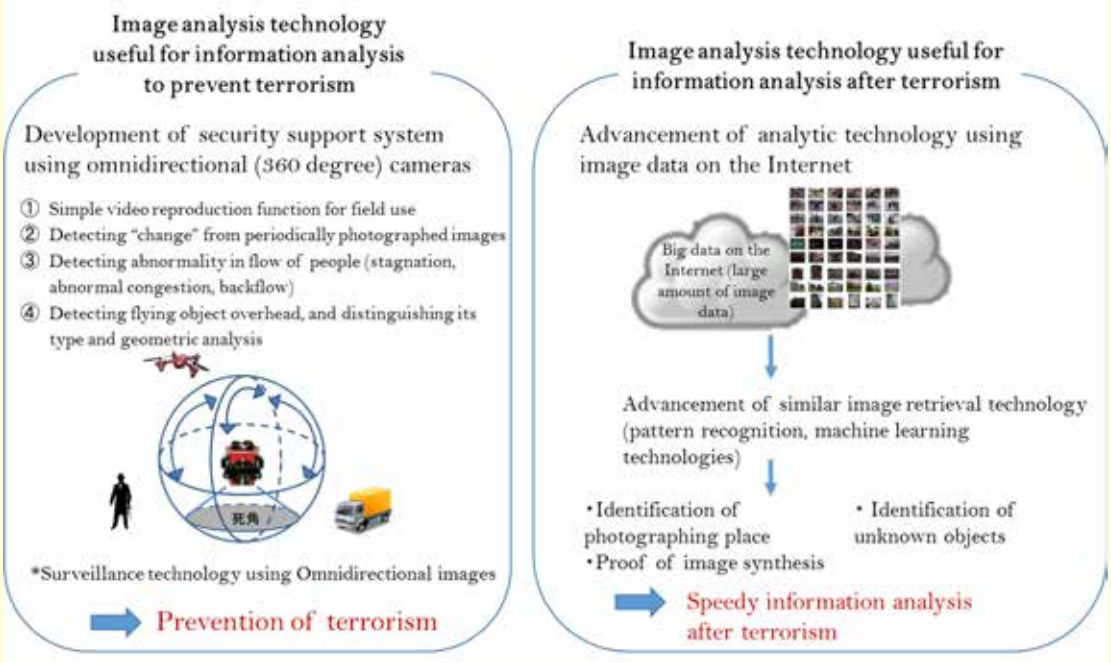
Figure 2-3-17 **Outline of the initiative for early practical use of rapidly progressing cutting-edge civil technologies**



Source: ATLA

With the aim of advancing image analysis technology useful for information analysis for terrorism prevention or reviews after terrorist acts, the National Research Institute of Police Science is working on the development of a security support system using omnidirectional cameras and R&D on analytic technologies using image data on the Internet (Figure 2-3-18).

Figure 2-3-18 **Outline of research for advancement of image analysis technology to address terrorism**



Source: National Police Agency

MOD has been conducting research to greatly improve the workability of unmanned vehicle operators by swiftly creating overview displays and 3D area maps suitable for remote control by integrating images obtained from multiple unmanned vehicles and laser scanner information in inhospitable disaster sites such as a the CBRN[1] contaminated environment. In order to support disaster relief activities of the SDF (Self-Defense Force), MOD is also conducting research on high-mobility powered suits that enable quick and agile action and travel on uneven ground while reducing weight load on personnel. Furthermore, in order to visualize CBRN contamination and present detailed contamination status and damage estimation, research is conducted on a threat determination system to estimate contamination source areas based on dispersion prediction considering detailed topography including buildings in midtown and information from sensors.

Table 2-3-19 **Major policies to address national security issues (FY2017)**

Ministry	Implemented by	Description
MOD	ATLA	Innovative Science & Technology Initiative for Security
		Initiative for short-term practical application of new technologies

1 Chemical, Biological, Radiological, Nuclear

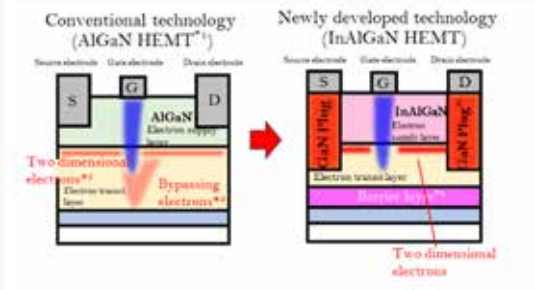
Column 2-6

One research result contributes to various problem solutions - Research results of the Innovative Science & Technology Initiative for Security

Expecting contribution to future R&D in the defense field, MOD's Innovative Science & Technology Initiative for Security solicits and commissions basic research on advanced civil technologies. Many research results with potential to contribute to problem solving in various fields have been made public under the initiative. (http://www.mod.go.jp/atla/funding/seika.html)

One example is increasing output of high frequency devices, which is one of the important element technologies common to radar, navigation support, communication, etc. Generally increasing transmission output of radio waves is accompanied by various adverse effects including increase in device size, heat generation and rising power consumption. To address these problems, Fujitsu Limited proposed and implemented research toward an innovative high-frequency device that will combine high output and low power consumption by introducing indium materials that can optimize device structure to transistors using gallium nitride (CaN-HEMT)[1]. The company succeeded in developing a power amplifier with the world's top power density applicable to high frequency band called W band (75 to 110 GHz) by using a research result of the initiative – technology to reduce internal resistance and leakage current of the device. Application of the technology to a wireless communication system between two points is expected to realize long-distance (more than 10km) and large-capacity (more than 10 gigabit /sec) communication. Several gigabits per second for several kilometers is the limit for existing technologies. Application of the new technology is expected in various fields from those related to our safety and security to everyday living, including early restoration means to address the breaking of optical fibers at the time of a disaster and temporary communication infrastructure for events.

As shown by this example, science and technologies are ambiguous. Therefore, it is important to ensure appropriate utilization of results for continued powerful promotion of scientific and technology innovations.



Device structure of GaN-H[1]
Provided by Fujitsu Limited

*1 HEMT: High Electron Mobility Transistors make electrons move at a high speed by joining different compound semiconductors and separating the layer that supplies electrons from the layer where electrons run. They are used for receivers for satellite broadcasting, mobile phone base stations, GPS receivers, etc., because of their excellent characteristics in high frequency band compared with ordinary transistors.

*2 Two dimensional electrons: electrons moving at a high speed from the source electrode to the drain electrode on the upper boundary surface of the electron transit layer

*3 Bypassing electrons: electrons that take a detour in the bottom side when the gate electrode is closed. They become leakage current causing deterioration of operating efficiency of the power amplifier.

*4 Barrier layer: layer set up to greatly reduce leakage current by reducing bypassing electrons during operation

*5 GaN Plug: Columnar GaN layer embedded immediately under source and drain electrodes. It reduces resistance and enables large current in the transistor through smooth supply of electrons from the source electrodes, etc. to the two-dimensional electron field.

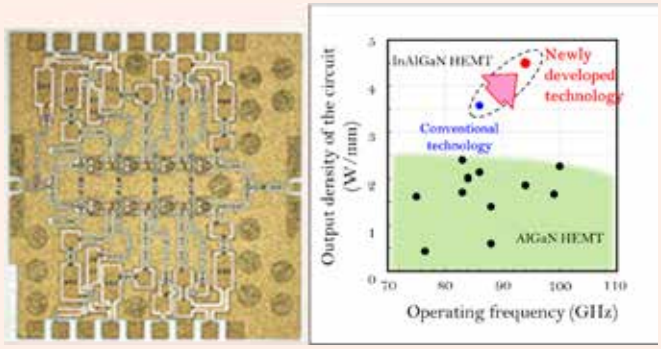


Photo (left) and Performance comparison (right) of Wband GaN-HEMT power amplifier[1]
Provided by Fujitsu Limited

1 Fujitsu Developed Gallium-Nitride HEMT Power Amplifier Featuring World's Highest Output in Millimeter-Wave W-Band http://www.prfujitsu.com/jp/news/2017/07/24.html (reference: 2018-04-03)

Section 3 Addressing Global Challenges and Contributing to Global Development

Response to Climate Change is a pressing issue for Japan and the world. Based on the Paris Agreement that became effective in November 2016, the country needs to enhance efforts to mitigate climate change by greatly reducing greenhouse gas emissions while making efforts for adaptation.

1 Addressing global climate change

(1) Development of technologies for observation of the earth environment and continued observation

A. The promotion of Earth observation

To understand current global warming trends, many countries and organizations worldwide have been observing the Earth by satellite, ground-based and maritime observation systems. To enhance the effectiveness of global efforts for tackling climate change problems, Earth observation data should be integrated and analyzed through international collaborations, to accumulate useful scientific knowledge as a basis for policymaking in each country. It is also important to develop the Global Earth Observation System of Systems (GEOSS), which consists of multiple systems that facilitate access by many countries and institutions to observation and other scientific data. The Group on Earth Observations (GEO) was established as an international framework to promote the development of GEOSS. It had 223 countries and institutions as members as of February 2018. Japan has been playing a leading role on the GEO Executive Committee.

B. Satellite-based observation

To promote satellite observations of the earth, JAXA has been operating the Global Change Observation Mission - Water "SHIZUKU" (GCOM-W) and the Advanced Land Observing Satellite-2 "DAICHI-2", and has been conducting R&D for the Global Change Observation Mission - Climate "SHIKISAI" (GCOM-C) and for other satellites (See Chapter 3, Section 4).

In order to help clarify climate change and its effects, MOE, with related ministries and agencies, has developed and is operating global carbon dioxide and methane observation technologies using the Greenhouse Gases Observing Satellite "IBUKI" (GOSAT[1]) and has continuously monitored greenhouse gases by using airplanes and ships, and monitors on the ground. With the aim of further promotion of climate change countermeasures, this satellite has been used for global observation to improve the estimation accuracy of GHG absorption and emission. GOSAT has been successfully clarifying the global concentration distributions of carbon dioxide and methane, as well as seasonal changes in these distributions. Based on GOSAT data, absorptions and emissions of carbon dioxide and methane are estimated by month and by subcontinent, three-dimensional carbon dioxide distribution data, and the average carbon dioxide concentration in the global atmosphere are estimated. An analysis of observation data of IBUKI indicated their usability as a verification tool for GHG emission inventory. With the aim of further improving the observation accuracy, IBUKI-2 (GOSAT-2) is scheduled for launch in FY 2018. By providing multi-point

1 Greenhouse gases Observing SATellite

observation data collected by the IBUKI (GOSAT) series the ministry will contribute to the science of climate change, global environmental monitoring and the formulation of measures against climate change. At the same time, by promoting utilization of the observation data for emissions comparison and assessment, it will contribute to the transparency of emissions by individual countries and their efforts on reduction.

Data of SHIZUKU (GCOM-W) launched for the purpose of elucidating the global mechanisms of climate change and the water cycle, and the data of the core satellite launched in cooperation with NASA under the international Global Precipitation Measurement (GPM) project are used to improve the accuracy of precipitation estimates by Japan Meteorological Agency. Not only are the data used for research on climate change, they are also used for various other purposes, including weather forecasting and fishing ground detection.

JMA verified that the use of SHIZUKU (GCOM-W) data has helped to increase the accuracy of precipitation estimates in numerical prediction as well as the accuracy of analyses for sea surface temperature and sea ice. JMA has used the same data from GCOM-W for a numerical prediction system that JMA operates routinely and for analyzing sea surface temperatures and sea ice. Observation data of the GPM core satellite has been used in the numerical forecasting system, which contributes to the improvement of the accuracy of precipitation estimates.

C. Ground and oceanographic observations

The marine environment is rapidly changing in recent years: sea temperature is rising and ocean acidification is progressing worldwide, for example. We need to understand the changes in the marine environment for preservation of oceans and marine resources and their sustainable use, and elucidation of global environment changes. To this end, JAMSTEC has been constructing an integrated marine observation network by combining drifting floats, moored buoys, observation by vessels and other means.

MEXT and JMA are participating in an ocean observing system (the Argo program[1]) for continuous observation of oceans around the world through international cooperation. The Argo program aims at the real-time monitoring and evaluation of oceans around the world based on Argo floats deployed in these oceans.

MEXT is promoting research and observation in various fields related to the Antarctic and Arctic, where it is possible to accurately measure global environmental changes. The Antarctic Research Programs have been administered by the Headquarters for the Japanese Antarctic Research Expedition (Chief of the headquarters: the minister of MEXT), in cooperation with other ministries and research institutions, including the National Institute of Polar Research (NIPR). They are collaborating with other nations and research and observation in the Antarctica has been conducted based on the 9th Six-Year Antarctic Research Program (FY2016- FY2021).

Regarding the Arctic, the Headquarters for Ocean Policy at the Prime Minister's Office decided Japan's Arctic Policy on October 16, 2015. Under the Arctic Challenge for Sustainability Project (ArCS), climate change in the Arctic and the impacts of such change on the global environment have been comprehensively studied to forecast such change and impacts with high accuracy and to clarify the socioeconomic effects of

1 Based on the understanding that environmental issues significantly and seriously affect the humanosphere, the Environment Research and Technology Development Fund, a policy-oriented competitive research fund, was created.

such impacts. The project aims to provide stakeholders with the obtained information so that they can make appropriate decisions and address issues. To this end, international joint research has been promoted, a center for international research has been developed and the fostering of young researchers has been promoted.

JAMSTEC has established the Institute of Arctic Climate and Environment Change Research to promote Arctic research. JAMSTEC is also developing autonomous underwater vehicle (AUV) capable of autonomous navigation and observation under sea ice and technologies for other elements. In order to clarify changes in the marine environment and ecosystem in the Arctic Ocean and its surrounding seas, it is conducting observation using the oceanographic research vessel Mirai from August to October when sea ice poses least obstacles. Furthermore, in FY2017 JAMSTEC conducted research and examination on arctic region research vessels that provide research platforms.

JMA has been conducting observation and analysis of GHGs, aerosols, ground radiation, the ozone layer and ultraviolet radiation in the atmosphere and oceans. By collecting and analyzing various observation data from ships, Argo floats and satellites, JMA provides information related to the global environment.

JMA has also been observing greenhouse gasses in the atmosphere at three sites in Japan and at the Showa Station in Antarctica. In addition, JMA is observing greenhouse gasses in seawater and in the atmosphere near seawater by using an ocean weather observation ship, and in the atmosphere at high elevations in the northwest Pacific Ocean by using an aircraft. These data and other observed global warming related data and their analyses are made available to the public. JMA has also been observing the ozone layer and ultraviolet rays in the atmosphere at four sites in Japan and at the Showa Station in Antarctica.

(2) Advancement of climate change prediction technologies using super computers, etc.

MEXT has been promoting R&D towards the creation of basic information that will be necessary for the management of diverse risks posed by climate change. For this purpose, the world's fastest supercomputers including the Earth Simulator are used to advance climate change prediction technologies through development of climate models, etc.

MRI under JMA has developed the MRI Earth System Model for global warming prediction. It can simulate the effects of aerosols on clouds, changes in the ozone layer and the carbon cycle. Using this model, the institute is making near-future climate change predictions (i.e., about 10-year lead time) and long-term predictions based on IPCC emissions scenarios. The institute has also developed a sophisticated cloud-resolving regional climate model that has sufficient resolution to simulate Japan's unique local climatic phenomena. The aim is spatially detailed regional climate warming prediction.

JAMSTEC has been making full use of its supercomputer systems to develop the most advanced predictive models and simulation techniques. These are used to elucidate the possible impacts of global environmental changes on Japan and to help solve climate change problems from the viewpoint of marine science.

(3) Development of information base integrating observation and prediction data

MEXT has developed the Data Integration and Analysis System (DIAS). DIAS integrates and analyzes Earth Observation data, climate change and social and economic data gleaned from Earth Observation satellites and from land and ocean observations to create useful information. The system has supported R&D

in Japan and abroad and produced results especially for water issues. In FY2016, MEXT launched the Program for the Development of Earth Environmental Information Platform. Under the program the ministry is working to establish a management structure to ensure its long-term stable use by a large number of users including enterprises in Japan and abroad, and also promoting development of common fundamental technologies contributing to solution of social challenges in various fields including disaster prevention, energy and agriculture.

For the creation, under the World Data System (WDS), of a scientific data platform that will be the largest size in the world and that is being promoted by the International Council for Science (ICSU[1]), NICT has been selected to host this endeavor's International Program Office. NICT is building a network with the Science Council of Japan (SCJ) and related domestic and international research institutions. By gathering scientific papers and their reference data on Earth observation, NICT is developing a global-scale science data platform that allows the stored data to be analyzed and is conducting R&D for reference relation analysis among reference data of different papers.

NICT is also analyzing data from the Superconducting Submillimeter-wave Limb-Emission Sounder (SMILES[2]) that NICT developed in cooperation with JAXA, and is providing stratospheric observation data. MIC has implemented R&D on the electromagnetic environment and on the use of radio waves in geospace, and has collected, managed, analyzed and distributed space/Earth observation data in an integrated manner. Additionally, the development of space environment informatics technology[3] has been promoted, with the aim of enhancing technologies for observation, sensing and numerical calculation, and for the processing of large amounts of data.

In addition, JMA is collecting observation data on the above items from ships, Argo Floats and satellites and by using other means, and has been analyzing such data. These results have been published in a report called The State of the Ocean Climate, which provides information on current conditions and the prospects for changes in oceanic fluctuations related to global warming.

GSI is developing technologies for data development using earth observation satellite data.

(4) Efforts for reduction in carbon dioxide and other emissions

Aiming at the practical use of Carbon Dioxide Capture and Storage (CCS[4]), METI is advancing R&D for the demonstration of an integrated system designed to separate and capture carbon dioxide from large carbon dioxide sources and store it underground at depths of more than 1,000 m, as well as developing technology to drastically reduce costs and improve safety.

In steel manufacturing, the ministry is developing innovative carbon dioxide emissions reduction technologies, including a technology to partially substitute hydrogen for coke as a reductant in steel

1 The International Council for Science (ICSU): This non-governmental, non-profit, global academic organization was established in 1931. Its mission is to strengthen international activities in the applied science and other science for the benefit of society.

2 Superconducting Submillimeter-Wave Limb-Emission Sounder: SMILES performs observations of the atmospheric limb by using an offset Cassegrain antenna. The high-sensitivity, low-noise superconducting receivers of SMILES receives submillimeter waves emitted by atmospheric trace species in order to measure the concentrations of ozone and other molecules. The frequency range from 300 GHz to 3,000. GHz is the submillimeter-wave range. GHz is the submillimeter-wave range. SMILES uses sub-millimeter waves ranging from 624 GHz through 650 GHz.

3 Space environment informatics technology is used for processing large quantities of diverse data collected from observations and simulations of the space environment and for extracting information from the processed data.

4 Carbon Dioxide Capture and Storage

manufacturing and separate and capture carbon dioxide from blast furnace gas toward further decarbonization.

MOE has been compiling (1) costs of separating and recovering most of carbon dioxide from exhaust gas from coal fired power plants, (2) design and construction of carbon dioxide separation/recovery equipment toward assessment of degradation in power generation efficiency and environmental impact, and (3) methods for smooth introduction of CCS suitable for Japan.

METI and MOE have jointly conducted geological investigations, including elastic wave explorations, to determine areas suitable for CCS in Japan.

With the aim of further reducing greenhouse gas (GHG) emissions in international marine transportation, IMLIT initiated the advanced vessel introduction plan authorization system in October 2017 to promote development and spread of LNG vessels and other advanced vessels using alternative fuels. In addition, toward development of GHG emissions reduction strategy by IMO[1] the ministry proposed concrete reduction goals and measures to achieve them ahead of other countries and is leading international negotiations.

With the aim of greatly reducing carbon dioxide emissions from ships, MPAT is conducting research on basic technologies that afford great reductions in environmental impact by facilitating the implementation of common-sense environmental regulations aimed at zero emissions.

MPAT is promoting research that includes onsite surveys in coastal areas and experiments aimed at quantitatively measuring the atmosphere/seawater gas exchange rate and the carbon flow between the seawater and benthic ecosystems (benthic flora, fauna and sediments). The aim is to establish a method for measuring blue carbon, which has potential for both domestic and international applications.

NILIM is conducting studies on: sewerage disposal technology to reduce greenhouse gas emissions and collect energy and resources; technology development to combine a comfortable indoor environment of homes/buildings and energy-saving performance, and; low-carbon urban development through improvement of the thermal environment of cities by using vegetation.

(5) Development of technologies to address climate change and their spread to economic and social activities

The Synthesis Report estimates total GHG emissions of the world in 2030 at about 57 billion tons. Based on the estimation, in order to achieve the goal of "below 2 degrees C" set by the Paris Agreement, it is necessary to control emissions to about 24 billion tons by 2050, which requires additional reduction exceeding 30 billion tons. In response, the National Energy and Environment Strategy for Technological Innovation (NESTI 2050) identifying innovation technologies with large reduction potential was decided by the Council for Science, Technology and Innovation (CSTI) in April 2016. The government is promoting these technologies and working to construct a system for R&D promotion.

In order to promote R&D of promising innovative technologies, the Cabinet Office developed and published a technology roadmap in September 2017, set up an investigative commission to identify bottleneck problems to be addressed on a priority basis toward innovations for drastic reduction of greenhouse gas emissions.

---

1 International Maritime Organization

To enable local governments to adapt to the effects of climate change, which will vary by region, by using results of R&D conducted by MEXT including forecast information on climate change, the ministry is conducting research on the following technologies in collaboration with local governments: 1) the highly reliable forecasting of climate change effects in the near future, 2) the high-resolution down-scaling of forecast data, 3) impact assessment of climate change and 4) assessment of the effectiveness of measures to address issues related to climate change. MEXT is also promoting Future Earth, which is a global initiative on global environment research including climate change in collaboration with stakeholders in Japan and abroad.

In FY2017 MAFF developed climate change adaptation technologies in agriculture, forestry and fishery, and technologies to address damage by wildlife. The ministry also developed a high-precision yield and quality prediction model and other means to assess the impact of climate change on agricultural and marine products. Furthermore, from a medium- to long-term viewpoint based on evaluation, MAFF has been promoting the development of plant varieties that are resistant to high temperature and drought by making the most of genome information, technologies for stable production adapted to the progress of warming and technologies to address pest damage. In addition, the ministry initiated the development of GHG emissions reduction technology in animal husbandry. MAFF is also promoting initiatives for climate change countermeasures and sustainable and stable food supply in developing countries in international cooperation.

MOE has been working on two strategic research tasks: (1)"Promotion of climate policies by assessing environmental impacts of SLCP[1], and exploring their reduction pathways" to propose best pathways for reduction of SLCP believed to be a factor of climate change and effective measures for their realization (S-12), and (2)"Comprehensive Strategic Research on the Mitigation of and Adaptation to Climate Change" to develop quantitative basic data for effective and efficient ways to take mitigation/adaptation measures and contribute to appropriate planning of climate change countermeasures as risk management(S-14). The ministry is comprehensively promoting the strategic studies and other research on observation/monitoring of climate change and its impact as well as prediction, assessment and countermeasures using the Environment Research and Technology Development Fund.

In order to promote consistent efforts for adaptation to the impact of climate change in a systematic and comprehensive way, the Cabinet decided the National Plan for Adaptation to the Impacts of Climate Change in November 2015. Based on the plan, the Climate Change Adaptation Platform, Japan (A-PLAT) was set up at NIES in August 2016 to support efforts by local governments and business operators. The platform has been providing the latest information regarding adaptation in coordination with relevant ministries and agencies. For comprehensive and plan-based promotion of necessary measures in close cooperation of relevant ministries and agencies, the Inter-ministry Liaison Conference on adaptation to the impact of climate change was held. In October 2017 the conference compiled the "Trial follow-up of the plan for adaptation to the impact of climate change."

MRI is addressing the development of real-time observation and monitoring technology for the detection of unusual meteorological phenomena, such as intense localized downpours (known in Japanese as "guerrilla rain"), by means of dual polarization radar, phased array radar and global positioning system (GPS). MRI is

1 Short Lived Climate Pollutants

also advancing the development of a numerical prediction model with high enough resolution to display intense localized downpours, in order to improve the accuracy of weather information and thereby to help reduce damage from local meteorological phenomena.

Table 2-3-20 Major policies to address global climate change (FY2017)

Ministry	Implemented by	Project
MEXT	MEXT	Initiative for Strategic Adaptation to Climate Change
	JAXA	Subsidies for R&D on the global observation system
MAFF	MAFF	R&D for response to climate change in the field of agriculture, forestry and fisheries
		Development of technology to mitigate impact of climate change in agriculture
METI	METI／Agency for Natural Resources and Energy (ANRE)	R&D on CO_2 separation/recovery technology
		R&D of CO_2 capture and storage for safe CCS implementation

2 Responding to biodiversity loss

The Intergovernmental Science-policy Platform on Biodiversity and Ecosystem Services (IPBES) was established with the aim of strengthening the coordination of science and policies regarding biodiversity and ecosystem service. At Japan's proposal IPBES TSU for Asia-Pacific Regional Assessment (IPBES-TSU-AP) was set up under the Institute for Global Environmental Strategies (IGES) in 2015. Through TSU-AP Japan supports development of assessment reports on biodiversity and ecosystem services in Asia and Oceania. For effective reflection of Japan's knowledge in assessment reports including the above, the country held the domestic liaison conference in February 2018 by gathering experts involved in IPBES and relevant ministries and agencies. At the 6th Plenary held in Medellin, Colombia, in March 2018, the abstract of the above-mentioned report for policy decision makers was approved and its main body was accepted. In addition, MOE started the "Predictive Estimation of Natural Capital and Ecosystem Services through Integration of Social and Ecological Systems" by using the Environment Research and Technology Development Fund. The research aims to strengthen the international link between science and policies through provision of knowledge for assessment by IPBES.

Japan has a part in and supports activities of the Global Biodiversity Information Facility (GBIF) that aims to collect data on biodiversity so that the data can be made available worldwide. Japan also provided GBIF with biodiversity data in cooperation with National Science Museum and National Institute of Genetics which are both GBIF nodes (data providing centers). Data accumulated by GBIF are expected to serve as fundamental data for evaluation at IPBES.

MAFF is developing a database and a system for higher-level analysis of fragmentary genomic information produced by next-generation genome analyzers, for the purpose of providing breeders and researchers at universities and private companies with information on the genes and genomes of agricultural, forestry and fishery products. In its gene bank project concerning agricultural biological resources, MAFF collects, preserves, assesses and provides biological genetic resources related to agriculture, and preserves and provides genomic resources, including DNA, of rice and other crops.

The National Institute of Technology and Evaluation (NITE) has been collecting, preserving and distributing biological genetic resources and has also been organizing information on these resources in terms of their genes and genetic lineages so as to make the information accessible to researchers and others.

It also joined a network of 27 organizations from 15 countries and regions that aims for the preservation and sustainable use of microbial resources and has actively supported Asian countries in their efforts to use biological resources by constructing cooperative relationships with them according to the Convention on Biological Diversity (CBD).

Furthermore the ministry has been promoting the development of empirical studies on basic technologies for the high-efficiency production of high value-added products (e.g., vaccines, functional foods) from genetically modified plants, thereby promoting the commercialization of safe, high-efficiency material production technologies that make the most of plant biological functions.

The adverse effects of global warming, ocean environmental degradation and overexploitation of marine species have become increasingly obvious. The conservation of marine biodiversity is also significant challenges for humans. In "Advancement of Technologies for Securing Living Marine Resources" under the Ocean Resource Use Promotion Technology Development Program, MEXT is implementing R&D for the purpose of comprehensively elucidating marine ecosystems. In the Strategic Basic Research Program of the JST, R&D has been conducted on technologies for observing and monitoring marine species. Research has been conducted for restoration of the marine ecosystem off the Pacific coast of Tohoku region damaged by tsunami.

Section 4 Pioneering Strategically Important Frontiers

In addition to enhancing industrial competitiveness and addressing economic and social challenges a range of science and technology to support the appropriate development, utilization, and management of the oceans and space serves as a firm foundation for Japan's subsistence. At the same time, since such science and technology have additional value, such as enabling Japan to earn admiration and respect in the international community and promoting the scientific education of citizens, it is necessary to continually enhance this asset based on a long-term perspective.

1 The promotion of oceanographic R&D

As an "oceanic state" that ranks as sixth in the world in terms of the size of the country's exclusive economic zone (EEZ), Japan needs to produce STI results befitting this status. For this purpose, it is important to steadily work on R&D of technologies for ocean surveys and observation—including areas of sea ice, deep seas, and below the seabed—and technologies for contributing to sustainable development and utilization of the seas, which includes biological resources, transportation, tourism, and environmental conservation, as well as technologies to help ensure the safety of the seas, and the scientific knowledge and fundamental technologies necessary to support all these efforts.

The Cabinet Office is promoting efforts to solve technology development challenges related to oceans in cooperation with the Headquarters for Ocean Policy and ensuring consistency with the Basic Plan on Ocean Policy (Cabinet Decision on April 26, 2013).

MEXT is promoting R&D in the marine S&T fields contributing to innovations toward creation of future

industries based on the R&D plan pertaining to ocean science and technology formulated at the CST's Subdivision on Ocean Development.

Using vessels, probes, observation equipment and other means, JAMSTEC has been conducting survey and research in ocean including the deep sea bottom and ice-infested waters that are difficult to access, as well as simulation using the obtained data and archiving and dissemination of the data. Using these technologies JAMSTEC is promoting basic research to elucidate the actual state of the areas that need further elucidation.

(1) Ocean survey and observation technologies

For the purpose of understanding the subseafloor microbiosphere, the mechanisms of ocean-trench earthquakes and tsunamis, and the genesis as well as the possible existence of marine resources, JAMSTEC has been advancing the development of technologies for drilling by using the deep-sea drilling vessel CHIKYU and technologies for real-time observation by using DONET. These technologies are also utilized for surveys, research and the development of other technologies.

The ministry has also been conducting research and surveys that focus on the seas around the Japanese archipelago and the entire Pacific Ocean. Specifically, crustal structures are explored by using research vessels, the manned research submersible SHINKAI 6500 and unmanned submersibles, towards deepening our understanding of phenomena related to the deep ocean floor, such as tsunamis and huge earthquakes that can cause devastating damage.

(2) Technologies contributing to sustainable ocean development, use, etc.

MEXT has been developing advanced key technologies necessary for ocean resource exploration and is using these technologies for research and exploration. Within the framework of the program for developing technologies for promoting the use of marine resources: system development for the wide-area exploration of ocean mineral resources, which started in FY2013, MEXT aims at promoting the transfer of technologies to private companies. For this purpose, cutting-edge sensor technologies developed by universities have been further advanced, efficient wide-area exploration systems have been developed by combining multiple sensors, and new exploitation techniques have been developed and verified for practical application (See Chapter 3 Section 1, 1(2)).

JAMSTEC has been conducting R&D for clarification of the origin of seafloor resources and establishment of effective survey and environmental assessment methods using ships, probes, cutting-edge sensors and other technologies toward sustainable use of resources buried in the sea areas surrounding Japan (See Chapter 3 Section 1, 1(2)).

MIC has been conducted R&D on next-generation satellite communication technologies for marine resource surveys, in order to improve the efficiency of marine resource surveys. MIC has been developing technologies to make Earth stations more compact and energy-efficient, and has been developing automatic satellite tracking systems.

(3) Technologies contributing to the securing of safety and security on the Oceans and preservation of ocean environment

The adverse effects of global warming, ocean environmental degradation and overexploitation of marine species have become increasingly obvious. The conservation of marine biodiversity and the sustainable use of marine biological resources are significant challenges for humans. In the "Advancement of Technologies for Securing Living Marine Resources" under the Ocean Resource Use Promotion Technology Development Program, MEXT is implementing R&D for the purpose of realizing innovative production based on an understanding of the physiology of marine species and for the purpose of comprehensively elucidating marine ecosystems. In the Strategic Basic Research Program of the JJST, R&D has been conducted on technologies for observing and monitoring marine species (See Chapter 3 Section 3-2).

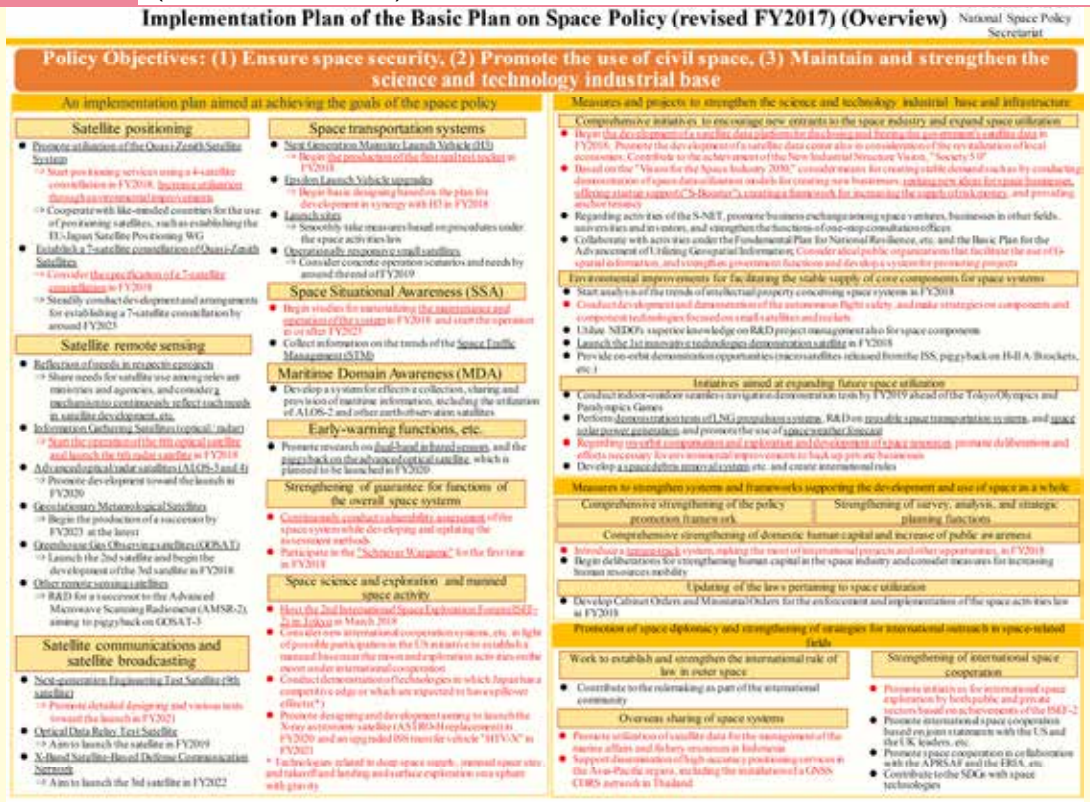
MPAT is conducting research on the development and improvement of techniques for safety evaluation of offshore structures and for reducing environmental impacts. These techniques are the basis of key technologies for the exploitation of ocean resources and energy.

JCG has been gathering information of ship movements for the purpose of ensuring safe marine transportation and improving operational efficiency. JCG is developing a system to predict vessel traffic flow and feed back the information to the vessels based on the analysis of these big data.

2 Promotion of R&D in space science

Space development and utilization including weather, communication, positioning and broadcasting satellites are indispensable for everyday lives of the people. They are also important in expanding intellectual property of mankind and nurturing dreams and hopes of the people. Japan is promoting space development and utilization comprehensively and systematically as a national strategy based on the Space Basic Law (Act No. 43 of 2008) and the Basic Plan on Space Policy (Cabinet Decision on April 1, 2016).

Table 2-3-21 **Points of the Implementation schedule of the Basic Plan on Space Policy (Revised in FY2017)**



Implementation Plan of the Basic Plan on Space Policy (revised FY2017) (Overview) National Space Policy Secretariat

Policy Objectives: (1) Ensure space security, (2) Promote the use of civil space, (3) Maintain and strengthen the science and technology industrial base

An implementation plan aimed at achieving the goals of the space policy

Satellite positioning

- Promote utilization of the Quasi-Zenith Satellite System
  - Start positioning services using a 4-satellite constellation in FY2018. Increase utilization through environmental improvements
  - Cooperate with like-minded countries for the use of positioning satellites, such as establishing the EU-Japan Satellite Positioning WG
- Establish a 7-satellite constellation of Quasi-Zenith Satellites
  - Consider the specification of a 7-satellite constellation in FY2018
  - Steadily conduct development and arrangements for establishing a 7-satellite constellation by around FY2023

Satellite remote sensing

- Reflection of needs in respective approaches
  - Share needs for satellite use among relevant ministries and agencies, and consider a mechanism to continuously reflect such needs in satellite development, etc.
- Information Gathering Satellites (optical / radar)
  - Start the operation of the 5th optical satellite and launch the 6th radar satellite in FY2018
- Advanced optical radar satellites (ALOS-3 and 4)
  - Promote development toward the launch in FY2020
- Geostationary Meteorological Satellites
  - Begin the production of a successor by FY2023 at the latest
- Greenhouse Gas Observing Satellites (GOSAT)
  - Launch the 2nd satellite and begin the development of the 3rd satellite in FY2018
- Other remote sensing satellites
  - R&D for a successor to the Advanced Microwave Scanning Radiometer (AMSR-2), aiming to piggyback on GOSAT-3

Satellite communications and satellite broadcasting

- Next-generation Engineering Test Satellite (9th satellite)
  - Promote detailed designing and various tests toward the launch in FY2021
- Optical Data Relay Test Satellite
  - Aim to launch the satellite in FY2019
- X-Band Satellite-Based Defense Communication Network
  - Aim to launch the 3rd satellite in FY2022

Space transportation systems

- Next Generation Mainstay Launch Vehicle (H3)
  - Begin the production of the first and test rocket in FY2018
- Epsilon Launch Vehicle upgrades
  - Begin basic designing based on the plan for development in synergy with H3 in FY2018
- Launch rates
  - Smoothly take measures based on procedures under the space activities law
- Operationally responsive small satellites
  - Consider concrete operation scenarios and needs by around the end of FY2019

Space Situational Awareness (SSA)

- Begin studies for materializing the maintenance and operation of the system in FY2018 and start the operation in or after FY2023
- Collect information on the trends of the Space Traffic Management (STM)

Maritime Domain Awareness (MDA)

- Develop a system for effective collection, sharing and provision of maritime information, including the utilization of ALOS-2 and other earth observation satellites

Early-warning functions, etc.

- Promote research on dual-band infrared sensors, and the piggyback on the advanced optical satellite, which is planned to be launched in FY2020

Strengthening of guarantee for functions of the overall space system

- Continuously conduct vulnerability assessment of the space system while developing and updating the countermeasure methods
- Participate in the "Schriever Wargame" for the first time in FY2018

Space science and exploration and manned space activity

- Host the 2nd International Space Exploration Forum (ISEF-2) in Tokyo in March 2018
- Consider new international cooperation systems, etc. in light of possible participation in the US initiative to establish a manned base near the moon and exploration activities on the moon under international cooperation
- Conduct demonstration of technologies in which Japan has a competitive edge or which are expected to have spillover effects(*)
- Promote designing and development aiming to launch the Solar astronomy satellite (ASTRO-H replacement) in FY2020 and an upgraded 6th launch for vehicle "HTV-X" in FY2021

* Technologies related to deep space supply, manned space stay and future off-and-landing and surface exploration on a planet with gravity

Measures and projects to strengthen the science and technology industrial base and infrastructure

Comprehensive initiatives to encourage new entrants to the space industry and expand space utilization

- Begin the development of a satellite data platform for distributing and processing government's satellite data in FY2018. Promote the development of a satellite data center also in consideration of the revitalization of local economies. Contribute to the achievement of the New Industrial Structure Vision, "Society 5.0"
- Based on the "Vision for the Space Industry 2030," consider means for creating stable demand such as by conducting demonstration of space data utilization models for creating new businesses, nurturing new players for space businesses, offering start-up support ("S-Booster"), creating a framework for increasing the supply of risk money, and providing anchor tenancy
- Regarding activities of the S-NET, promote business exchange among space ventures, businesses in other fields, universities and investors, and strengthen the functions of one-stop consultation offices
- Collaborate with activities under the Fundamental Plan for National Resilience, etc. and the Basic Plan for the Advancement of Utilizing Geospatial Information, Consider ideal public organizations that facilitate the use of (i) spatial information, and strengthen government functions and develop a system for promoting projects

Environmental improvements for facilitating the stable supply of core components for space systems

- Start analysis of the trends of intellectual property concerning space systems in FY2018
- Conduct development and demonstration of the autonomous flight safety, and make strategies on components and component technologies focused on small satellites and rockets
- Utilize NEDO's superior knowledge on R&D project management also for space components
- Launch the 1st innovative technologies demonstration satellite in FY2018
- Provide on-orbit demonstration opportunities (micro satellites released from the ISS, piggyback on H-II A Rockets, etc.)

Initiatives aimed at expanding future space utilization

- Conduct indoor-outdoor seamless navigation demonstration tests by FY2019 ahead of the Tokyo Olympics and Paralympics Games
- Perform demonstration tests of LNG propulsion systems, R&D on reusable space transportation systems, and space solar power generation, and promote the use of space weather forecast
- Regarding on-orbit transportation and exploration and development of space resources, promote deliberations and efforts necessary for environmental improvements to back up private businesses
- Develop a space debris removal system etc. and create international rules

Measures to strengthen systems and frameworks supporting the development and use of space as a whole

Comprehensive strengthening of the policy promotion framework

Strengthening of survey, analysis, and strategic planning functions

Comprehensive strengthening of domestic human capital and increase of public awareness

- Introduce a human track system, making the most of international projects and other opportunities, in FY2018
- Begin deliberations for strengthening human capital in the space industry and consider measures for increasing human resources mobility

Updating of the laws pertaining to space utilization

- Develop Cabinet Orders and Ministerial Orders for the enforcement and implementation of the space activities law in FY2018

Promotion of space diplomacy and strengthening of strategies for international outreach in space-related fields

Work to establish and strengthen the international rule of law in outer space

- Contribute to the rulemaking as part of the international community

Overseas sharing of space systems

- Promote utilization of satellite data for the management of the marine affairs and fishery resources in Indonesia
- Support dissemination of high-accuracy positioning services in the Asia-Pacific region, including the installation of a GNSS CORS network in Thailand

Strengthening of international space cooperation

- Promote initiatives for international space exploration by both public and private sectors based on achievements of the ISEF-2
- Promote international space cooperation based on joint statements with the US and the UK leaders, etc.
- Promote space cooperation in collaboration with the APRSAF and the ERIA, etc.
- Contribute to the SDGs with space technologies

Source: Cabinet Office

(1) Space transportation systems

Space transportation systems are essential for the utilization of space, because these are an integral part of technologies for satellite launches. Technologies for sending satellites to their designated altitudes whenever needed are vital for the autonomy of Japan's space activities. The development of a new flagship rocket was formally started in FY 2014 to expand Japan's autonomous space activities and ensure international competitiveness. The first new rocket is scheduled for launch in FY2030.

Launch of H-IIA F37 (left) and Epsilon-3 (right)
Source: JAXA

Using H-IIA, H-IIB and Epsilon, our key rockets, Japan successfully launched the Quasi-Zenith Satellite System MICHIBIKI 2, 3 and 4 in June, August and October 2017, the climate change observation satellite SHIKISAI (GCOM-C) and the Super Low Altitude Test Satellite TSUBAME (SLATS) in December of the same year, a high-performance small radar satellite (ASNARO-2[1]) in January 2018 and the information gathering satellite Optical 6 in February of the same year.

1 Advanced Satellite with New system Architecture for Observation

(2) Global positioning satellite systems

Regarding global positioning satellite systems, MIC, MEXT, METI and MLIT have been collaborating on demonstration experiments that utilize the Quasi-Zenith Satellite-1 MICHIBIKI, which affords high-precision positioning that is unaffected by mountains or tall buildings. The Cabinet Office started the development of a practical system in FY2012 and succeeded in launch of the 2nd, 3rd and 4th satellites in FY2017, establishing a 4-satellite system including the first satellite launched in FY2010 toward the start of the service in FY2018. The Cabinet Office is also advancing R&D of positioning technologies with the aim of establishing the 7-satellite system that will enable continuous positioning by around FY2023.

Column 2-7

High-precision positioning by Quasi-Zenith Satellite System MICHIBIKI

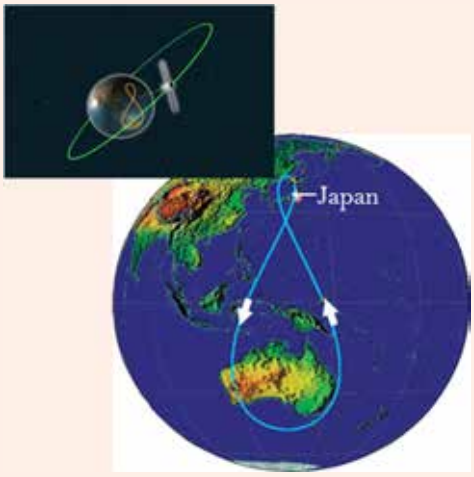
In 2010 the first satellite of the Quasi-Zenith Satellite System MICHIBIKI was launched, followed by the launch of three satellites in 2017.

The Quasi-Zenith Satellite System is Japan's unique satellite positioning system, the key component of which is positioning satellites on a quasi-zenith orbit. The system is sometimes called Japanese GPS. MICHIBIKI deploys three satellites on a quasi-zenith orbit (orbit drawing a figure of 8 from Japan to Oceania to maintain a high elevation angle for an extended number of hours) and one on a stationary orbit.

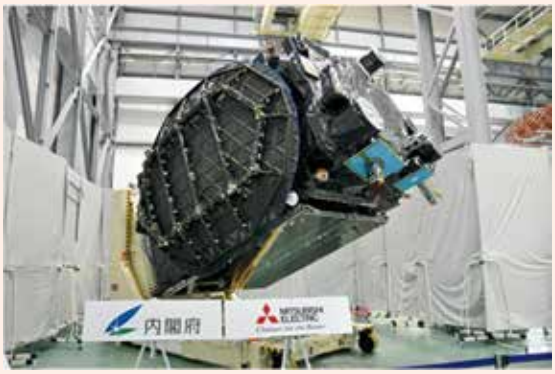
MICHIBIKI has three features: (1) expansion of positioning opportunities by staying at high elevation angle (complementing GPS), (2) signal distribution enabling centimeter-level positioning (reinforcing GPS) and (3) a messaging function.

Efforts are made to use the high-precision positioning information service at centimeter level provided by MICHIBIKI in automatic driving of automobiles and farm machines, snowplow operation support and other purposes. Demonstrations are also conducted for collection of evacuee information in shelters at the time of a disaster and for services to deliver tsunami and other disaster information to car navigation and outdoor digital displays.

MICHIBIKI: that will start its service in FY2018, is of a very great significance as infrastructure of the new age to create new services and deliver safety and security to the citizens.



Quasi-zenith orbit of MICHIBIKI
Source: Cabinet Office



MICHIBIKI-3
Source: Cabinet Office

(3) Satellite communication and broadcasting systems

The Japanese government's intention to launch an engineering test satellite around FY2021 is explicitly stated in its Basic Plan on Space Policy in order to realize internationally competitive next generation stationary geostationary communication satellites. To this end, MIC and MEXT have been developing the Engineering Test Satellite 9 since FY2016. This satellite will be developed for the purpose of demonstrating technologies of electric propulsion, high-power generation, and flexible payload. Furthermore, experiments were conducted to develop and demonstrate the satellite-based gigabit-class Internet communications

technology, using ultra-fast Internet satellite KIZUNA (WINDS[1]).

(4) Earth observing system

MOE launched Ibuki in FY 2012 to promote climate change countermeasures and the launch of IBUKI 2 is scheduled in FY2018 with the aim of further improving the observation accuracy.

Global Change Observation Mission - Climate "SHIKISAI" (GCOM-C)
Source: JAXA

Data collected by SHIZUKU (GCOM-W) launched by JAXA in May 2012 and the GPM core satellite launched in February 2014 in cooperation with NASA under the international Global Precipitation Measurement (GPM) project are used by JMA to improve the accuracy of precipitation estimates and for various other purposes, including weather forecasting and fishing ground detection (See Chapter 3 Section 3, 1(1)).

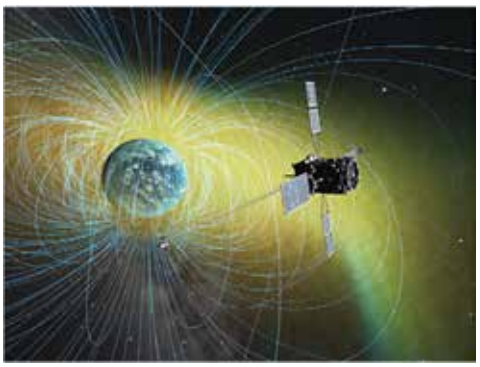
JAXA is also operating SHIKISAI that was launched in December 2017.

In addition, DAICHI-2 (ALOS-2) was launched in May 2014. The satellite is contributing to disaster prevention and management, and in solutions to global issues such as global warming through monitoring of various disasters, grasping of damage situations and the observation of forests, ice of Polar Regions, etc.

MEXT and JAXA are jointly working with MOD on development of a space monitoring system for the ground-based observation of space debris to contribute to stable operation of Japan's satellites, and also conducting research on technologies for mounting highly sensitive infrared sensors on satellites. Their other development efforts include advanced optical satellites (ALOS-3) capable of wide-area, high-resolution imaging, advanced radar satellites (ALOS-4), and the development of optical data relay satellites that can achieve inter-satellite optical communication.

(5) Space science and exploration

Regarding R&D in space science, JAXA has been playing a pivotal role. JAXA has achieved globally unrivaled results in X-ray and infrared astronomical observation, such as by developing and operating the world's first satellite for simultaneous X-ray photography and X-ray spectrography and by using the Hayabusa probe to collect samples from the asteroid Itokawa. Geospace probe ARASE launched in December 2016 is observing plasma in geospace around the earth with the aim of deepening the understanding of the space environment and interaction between the earth and solar activities including aurora and space storms. HAYABUSA 2, an asteroid explorer launched in December 2014, is scheduled to arrive at the Ryugu asteroid in 2018 and return to Earth in 2020 after



Geospace Probe ARASE
Source: JAXA

1 Wideband InterNetworking engineering test and Demonstration Satellite

collecting samples.

Venus Climate Orbiter AKATSUKI (PLANET-C) that was put into orbit around Venus in December 2015 started steady observation in April 2016 and has been conducting observation aimed at elucidation of mechanism of the atmosphere of Venus. In addition, JAXA is conducting development of the small moon landing demonstrator (SLIM) in an attempt to conduct Japan's first lunar landing and an alternative x-ray astronomical satellite (both are scheduled for launch in FY2020) and the Mercury Magnetospheric Orbiter for the BepiColombo international collaborative mission to Mercury (scheduled for launch around autumn 2018), which is being conducted in cooperation with the European Space Agency (ESA). JAXA has been active in establishing a leading position in the world as well as in promoting R&D on space science that helps broaden the frontiers of space for humankind.

(6) Manned space activities

The International Space Station (ISS) Program [1] is an international project collaboratively implemented by fifteen countries: Japan, the U.S.A., Europe, Canada and Russia. In this project, Japan assumes the role of developing and operating the KIBO (JEM) and the KOUNOTORI (HTV) automated cargo spacecraft. KIBO has been in service since its completion in July 2009, and KOUNOTORI has been used to resupply KIBO and the ISS. Japanese astronauts have carried out long-stay missions aboard the International Space Station. The Japanese team has achieved various things, such as establishing manned and unmanned space technologies, establishing an international presence for Japan, expanding the space industry, contributing to society based on social benefits accruing from the use of space (e.g. generating high-quality protein crystals leading to drug discovery, acquiring medical knowledge, creating materials useful for next-generation semiconductors and launching ultra-small satellites), and educating young people. During a long stay at ISS starting from December 2017 Astronaut Norishige Kanai conducted various science experiments using KIBO and operated systems of ISS facilities. In December 2015, the Japanese government signed an agreement with the U.S. government on a new framework for bilateral cooperation and formally decided to extend Japan's participation in the space station program through 2024. For the future, Japan intends to use a new spacecraft (HTV-X), considering future ripple effects, and has been

Astronaut Norishige Kanai

Source: JAXA and NASA

KOUNOTORI 6 grasped by an ISS robot arm

Source: JAXA and NASA

1 The International Space Station is a cooperative program based on the ISS Intergovernmental Agreement between Europe, the U.S.A., Russia, Canada, and Japan for the joint development, operation and utilization of a permanently inhabited Space Station in low Earth orbit (about 400 km above the Earth's surface).

advancing its development toward launch in 2021.

The International Space Exploration Coordination Group (ISECG), which consists of 15 space agencies from countries around the world, has been advancing studies on a sustainable international space exploration plan. Under this plan, the ISS will be maximally used for staged missions to Mars that start with unmanned exploration and are followed by manned exploration.

(7) Efforts for enhancing the use of space

Concerning the use of space, MEXT established a system for increasing the utilization of expertise possessed by government, industry and academia. Under this system, entrustment expense fees for the promotion of aerospace science and technology is used for the purpose of expanding the base of space users by discovering potential users of satellites and developing new utilization methods. Using this system MEXT continues R&D on space utilization technologies with a view to their practical use in human resource development, disaster prevention, the environment and other aerospace fields.

METI has been promoting R&D on small high-performance satellites that compare well with large satellites in performance and are built at low cost in a relatively short period of time. The small high-performance radar satellite (ASNARO-2) was launched in January 2018. R&D is also advanced regarding space equipment that is internationally competitive, sensors for the exploration of mineral resources using satellite remote sensing technologies and other satellite-based technologies, including those of data processing and analysis.

Column 2-8

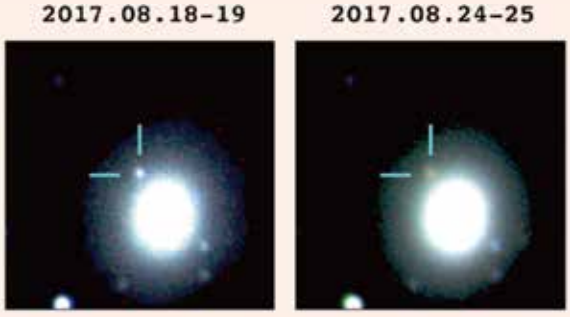
Is this space alchemy? – Heavy element formation found by new astronomy

There are more than 100 kinds of elements including hydrogen and carbon in the universe. It is known that there were only hydrogen and helium at the early stage of the formation of the universe, but elements up to iron came in to existence when stars were born and nuclear fusion reactions occurred at the center of the stars. It was believed that gold, platinum, rare earth and other elements heavier than iron had been formed by supernova explosion at the end of life of heavy stars. However, progress of research showed that supernova explosion could not create heavy elements such as gold, platinum and uranium that now exist in the universe. Consequently, where in space such elements are formed has become one of the big questions in astronomy and physics.

On August 17, 2017 gravitational wave telescopes of the United States and Europe detected gravitational waves that were considered to be generated through the coalescence of neutron stars. Japan's gravitational wave tracking team represented by Professor Michitoshi Yoshida of the National Astronomical Observatory of Japan discovered and tracked lights accompanying the gravitational waves using the Subaru telescope of the observatory, and succeeded first in the world in capturing the scene of the bright heavenly body getting darker and darker.

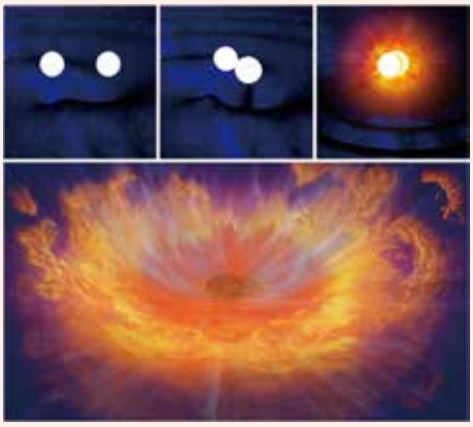
The light that will be emitted from the coalescence of neutron stars has been theoretically simulated using various patterns. Among the simulations, "kilonova" that is a light emission phenomenon when elements heavier than iron are synthesized well corresponds with the observation. This provided observational evidence that gold, etc. are generated by the coalescence of binary neutron stars, which is a big step toward elucidation of the origin of heavy elements in the universe.

The research discovered the unknown astronomical phenomenon by combining observation of gravitational waves and optical infrared measurement. Discovery of such phenomena had been left to chance in the past. Multi-messenger astronomy that combines observations of gravitational waves and light is expected to develop as a new means for exploration of space by humans.



Source of gravitational waves photographed by the gravitational wave tracking team of Japan Observations from August 24 to 25 of 2017 show dimming of the heavenly body

Provided by the National Astronomical Observatory of Japan, Nagoya University and Kagoshima University



Imaginary drawing of kilonova: provided by the National Astronomical Observatory of Japan

Table 2-3-22 Major policies to open up frontiers important for national strategies (FY2017)

Ministry	Implemented by	Project
CAO	National Space Policy Secretariat	Promotion of practical Quasi-Zenith Satellite System project
MEXT	MEXT	Japanese Antarctic Research Program
		The Arctic Challenge for Sustainability Project
		Expenses necessary for the coordinated promotion of aerospace technologies
	JAXA	Grants for ISS development
		Subsidy for R&D on earth observation system
		Subsidy for advancement of core rockets
MLIT	MLIT	Comprehensive measures for the strategic promotion of the marine industry
	JCG	Promotion of marine research in the EEZ of Japan